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INDEX

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THREE YEARS' EXPERIENCE WITH SODIUM-FLUORIDE THERAPY OF OSTEOPOROSIS

J Franke, H Rempel & M Franke

Accepted 2 x 73

The importance that has been attributed to osteoporosis in recent times is demonstrated by figures given by Lutwak & Whedon (1969) In the U S more than 4 million people were found to suffer from osteoporosis Smith & Rizek (1966) even estimated that 14 million women in the U S show a significant vertebral atrophy, and about 1 6 million have dorsolumbar vertebral fractures without symptoms The incidence of advanced osteoporosis in the male population is much lower with advanced age (e g 5 to 10 per cent over 50 years of age)

In spite of the above mentioned importance of osteoporosis the success of previous therapy methods was not encouraging

As we have seen massive osteosclerosis (Franke 1968 a, b, 1972 a, b, d Runge et al 1972) in many patients with industrial fluorosis, and encouraged by the good results with the treatment of the osteoporosis with sodium fluoride reported in the literature (Rich et al 1961, 1964, 1966 Bernstein et al 1963 1967, Cohen & Rubini 1965, Adams & Jowsey 1965 Reutter & Siebenmann 1965, Cass et al 1966, Luckert et al 1967, Reutter 1967 1970 Jowsey et al 1968 a b, 1971, Cohen et al 1969, Kuhlencordt et al 1969 1970, Schenk et al 1970 Merz et al 1970, Thiebaud et al 1970 a b Dalderup 1970, Beickert 1971) as well as by reports of lower incidence of osteoporosis in high fluoride areas in Texas and North Dakota (Leone et al 1955, Leone 1960, Bernstein et al 1966) we started sodium fluoride therapy in January 1969 A report on our first results of this treatment was given by Mattner & Franke at the Congress of the Orthopaedic Society of the GDR in

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Presented in part at the Fourth International Osteological Symposium Sept 27 30 1972 in Prague. Supported by Forschungsverband "Arbeitsmedizin" of the GDR.

Table 1 Subjective results of 34 patients with osteoporosis after 13 to 42 months treatment with sodium fluoride

Time of the treatment	Group 1 painless or distinctly improved	Group 2 improved	Group 3 unchanged	Group 4 deteriorated	*Total numbers*
3-42 months	19	4	5	6	34
7 42 months	15	3	4	4	26

We examined the 24 h urinary excretion of fluorine and the conditions of the gastric juice in order to find causes for the failure of our treatment in a few patients The 24 h excretion of fluorine was controlled twice a year during the NaF treatment We determined the normal acidity hyper and hypoacidity with the indicator tablets (Acidotest of Chinoin Budapest Hungary)

RESULTS

Subjective

Table 1 shows the subjective results of the treatment Group 1 involves painless patients and persons with intermittent slight back pains Group 2 involves patients with distinctly diminished complaints, which temporarily disappear, and with stronger load capacity of the skeleton Both groups comprise 23 patients, i e that more than two-thirds of the patients felt better after the fluoride therapy An isolated evaluation of the patients treated for 27 to 42 months and having received much reduced doses in the last half to one year (upper part of Table 1) yielded similar results (18 of 26 patients show an improvement)

Clinical

Table 2 shows the behaviour of the clinical symptoms direct and indirect compression pain of the spine, compression pain of the chest, sensitivity to tapping of the spine and body height in relation to the subjective disorders There is a good correlation and a distinct improvement of these findings in more than half of the patients

Radiological

In the normal usual x ray picture we could demonstrate a distinct increase of the density of the vertebral bone and an enlargement of the

1971 The purpose of this paper is to demonstrate our experiences successes and failures with the NaF therapy of osteoporosis

MATERIAL AND METHODS

Since that time we have treated 46 patients with sodium fluoride In the present paper 33 patients between 31 and 69 years of age with ideopathic osteoporosis are evaluated and one patient with steroid osteoporosis These patients were treated for a period 13 to 42 months with sodium fluoride The time of treatment of the 12 missing patients was too short (under 12 months)

Osteoporosis was diagnosed clinically (diffuse bone pains loss of height indirect and direct compression pain of the spine) roentgenologically (diminution of the mineral content ballooned disks compression vertebral fractures determination of the corticalis index according to Barnett & Nordin (1960), histologically by means of iliac crest biopsy (diminution of the bone mass exclusion of other bone diseases) and biochemically (failure of specific abnormalities)

The patients were given 20 to 60 *mg sodium fluoride per day in three portions* either as 10 or 20 mg powder or as tablets (Fluoretten forte) After the onset of the effect of fluoride (approximately after 1 5 to 2 years) we reduced the daily doses to 10 to 20 mg sodium fluoride or we passed over to the interval therapy with a 4 to 8 weeks pause

Once a year we carried out an accurate clinical examination such as measuring the body height the indirect and direct compression pain of the spine and the chest and the sensitivity to tapping of the spine Patients came to our clinic at intervals of 6 to 8 weeks in order to have the serum calcium and phosphorus levels alkaline and acid phosphatase determined

Each year we carried out a radiological control (thoracic and lumbal spinal column in 2 planes and pelvis) As the usual x ray picture shows only changes of the bone density of 20 to 40 per cent mineral loss (von Leitner 1969 Heuel 1970) we used a method of comparative radiological densitometry We took an x ray picture of the thoracolumbal transition with an aluminium wedge (9 steps) that lay in an 18 cm high water column beside the patient lying on his side In a vertebral body the relative radiological change of the density was measured with the *photometer (Schnellphotometer des VEB Carl Zeiss Jena) before the beginning of* the treatment and then once a year under equal conditions With our method it is not possible to determine the absolute concentration of hydroxyapatite in the vertebral body

In 10 patients we carried out a second iliac crest biopsy after 14 to 27 months of fluoride therapy The bone material was decalcified with nitric acid and stained with azan hematoxylin eosin PAS alcian blue In addition we examined *these* preparations histomorphometrically With the eyepiecemicrometer (VEB Carl Zeiss Jena) we determined the average thickness of the trabeculae in the biopsy cylinders before and after treatment with NaF We measured about 20 trabeculae per patient Simultaneously we determined the volumetric density of the bone with an integration eyepiece on the basis of the point counting volumetry We counted on the average 10 visual fields per biopsy cylinder The measurings were compared before and after treatment and secured statistically by means of Student s t test

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1*

Table 2 Clinical results of 34 patients with osteoporosis after 14 to 42 months of treatment with sodium fluoride

Time of treatment	Group 1 – clinical			Group 2 – clinical			Group 3 – clinical			Group 4 – clinical			total numbers clin		
	im-proved	un-changed	dete-riorated	im-proved	un-changed	dete-riorated	im-proved	un-changed	dete-riorated	im-proved	un-changed	dete-riorated	im-proved	un-changed	dete-riorated
13–42 months	12	7	–	3	1	–	3	1	1	–	2	4	18	11	5
27–42 months	10	5	–	2	1	–	3	1	–	–	1	3	15	8	3



Figure 1 Pat K K The skeleton shows a clear remineralization after 2 years of treatment with 40 to 60 mg sodium fluoride per day

bone trabeculae in 6 patients (only males) with a dosage of 30 to 60 mg/sodium fluoride per day after 18 to 33 months (Figure 1)

In groups 3 and 4 three patients showed an impairment of the radiological findings in the form of a fracture of the femur and two fractures of vertebral bodies By means of our densitometry method we examined 23 patients after 1 to 2 years of treatment Table 3 shows an increase of the bone density in 18 persons an unchanged density in one person and a decrease in 4 patients The control of the densitometry revealed the same trend after two to three years of fluoride

Table 2 *Clinical results of 34 patients with osteoporosis after 14 to 42 months of treatment with sodium fluoride.*

Time of treatment	Group 1 – clinical			Group 2 – clinical			Group 3 – clinical			Group 4 – clinical			total numbers clin.		
	im-pro-ved	un-chan-ged	dete-rio-rated	im-pro-ved	un-chan-ged	dete-rio-rated	im-pro ved	un-chan-ged	dete-rio-rated	im-pro-ved	un-chan-ged	dete-rio-rated	im-pro-ved	un-chan-ged	dete-rio-rated
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Table 3 Results of the comparative radiological densitometry in 23 patients with osteoporosis after 1 to 2 years of treatment with sodium fluoride in relation to the subjective success of this therapy

Group 1 13 patients with distinct improvement or painless				Group 2 3 patients with improvement				Group 3 5 patients with unchanged complaints				Group 4 2 patients with deterioration			
++	+	=	—	++	+	=	—	++	+	≈	—	++	+	=	—
4	8	0	1	2	1	0	0	0	2	1	2	0	1	0	1

++ = distinctly improved e g : increase of the density of the vertebral body of 4 or more steps in the aluminium wedge = 6 patients
\+ = improved e g · increase of the density of the vertebral body of 1 to 3 steps in the aluminium wedge = 12 patients
≈ = unchanged e g · no increase of the density = 1 patient
— = deteriorated e g decrease of the density of the vertebral body of 1 to 2 steps in the aluminium wedge = 4 patients

therapy An accurate statement was not possible at this time because of changed technical conditions (installation of a new x-ray-apparatus)

Biochemical

Blood phosphate levels, the plasma alkaline and acid phosphatase levels did not show any distinct changes The blood calcium levels, however, showed a significant increase (Student's t-test) in the course of the treatment (Figure 2)

The urinary excretion of fluoride did not show any positive trend resulting from therapy However, we found a surprising result in the evaluation of the gastric acid Of the 11 patients of groups 3 and 4 seven patients showed a reduction or a complete lack of gastric acid But in groups 1 and 2, 4 patients only out of 21 had a reduction of gastric acid The difference was significant in the χ^2-test with 1 per cent likelihood of error

Histological

In our histological investigations we found a distinct increase in the bone mass in spite of the small dose we had applied (Figure 3)

Histomorphometrically we found in 8 patients in measuring the average thickness of the trabeculae before and after the NaF-treatment

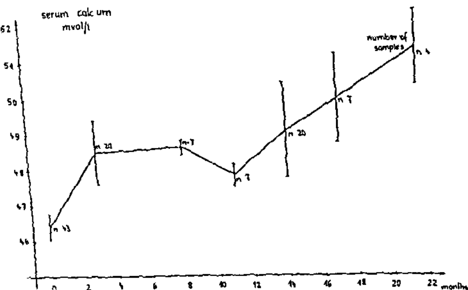


Figure 2 The average levels of the serum calcium before and during the NaF therapy (The levels for the months 1–6 and 13 18 differ significantly from the starting levels according to Student's t test)

a significant increase to 70 μm and in determining the volumetric bone density by means of point counting volumetry an increase of the bone mass to 16 per cent (Table 4) The results were made sure by means of the Student t test

The new bone formation developed subperiostally in the form of fibrous bone formation with beginning transformation in lamellar bone (Figure 4) and on previously existing trabeculae (Figure 5)

The newly formed bone is in particular irregular and atypical in the compacta Figure 6 shows a strongly thickened compacta with irregularly arranged osteons and enlarged cavities of osteocytes with osteoid between them Spread osteoid seams and the so called "mottled bone according to Johnson (1965) were found only rarely In one instance we could identify a so-called spongiosation of corticalis which we (Franke et al 1971 1972 a c) and other authors (Weinmann & Sicher 1955) had established in human and experimental animal bone fluorosis (Figure 7)

In the microradiogram for which we are indebted to Prof Dr habil Lencordt Hamburg the newly formed bone shows enlarged osteocytes lacunae but almost normal mineralization (Figure 8)



Figure 3 The increase of the bone mass in the NaF therapy in 2 patients
left side—before the treatment HE 1 50
right side—after the theatment HE 1 50



Figure 3 The increase of the bone mass in the NaF-therapy in 2 patients left side—before the treatment H.E. 1 50 right side—after the theatment H.E 1 50



Figure 4 Subperiostal new formation of fibrous bone with transformation in lamellar bone (Azan 1 80)

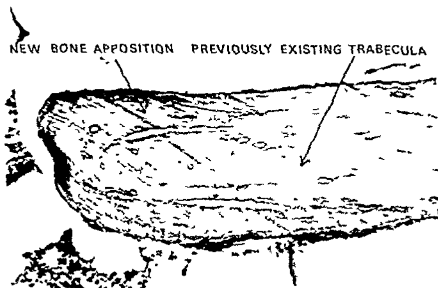


Figure 5 Distinct apposition of new bone on previously existing trabecula (H E 1 130)

Table 4 Histomorphometric results of the iliac crest biopsies of 10 patients with osteoporosis before and after treatment with sodium fluoride

Patient	Dose in mg NaF per day	Time of treatment in months	Result group	Average thickness of the trabeculae in μm			Volumetric bone density		
				before treatment	after treatment	increase significant	before treatment	treatment after	increase significant
1 K K	40 60	24	1	98 0	168 5	yes	30 4	38 9	yes
2 F F	40	18	2	115 4	115 6	no	21 6	29 5	yes
3 E B	35 40	18	3	90 4	113 9	yes	15 1	25 0	yes
3 J J	20 60	14	2	119 0	179 5	yes	26 2	30 6	no
5 K Kh	20 40	18	1	109 3	120 2	no	27 1	34 3	no
6 M H	30 40	19	4	98 6	98 9	no	25 8	21 7	no
7 G R	40 53	14	2	125 0	171 7	yes	26 1	32 5	yes
8 H H	20 30	18	1	89 8	135 7	yes	23 5	30 8	yes
9 H P	30 40	14	1	–	168 0	–	–	30 6	–
10 B I	20–30	27	1	110 9	158 5	yes	20 5	36 5	yes



Figure 8 Microradiogram Distinct bone apposition around previously existing tra beculae is to be seen The new formed bone shows enlarged cavities for osteocytes but good mineralization (1 50)

Side effects

In the beginning of the therapy we observed the following side effects nausea, sensation of repletion gastric disorders, anorexia vomitus and diarrhea The patients with vegetative and pre existing gastrointestinal disorders suffered from these complaints more violently Since there were no "enteric coated tablets' available, these gastrointestinal complaints appeared in particular in doses over 40 to 60 mg NaF per day The highest dose which was tolerated by a patient was 80 mg NaF per day Patients with known hyperacidity could not take in more than 20 mg NaF per day

Powder and tablets were tolerated differently In most patients these disturbances diminished spontaneously after a certain time or through application of sodium fluoride with much liquid after the meals

In 8 patients we observed a very unpleasant side effect, also described by other authors (Rich et al 1964, Lukert et al 1967, Bernstein & Cohen 1967, Thiebaud et al 1970 a) These patients complained of severe pain in the feet, knee or hip joints Some of them had earlier



Figure 6 Strong thickened compacta with enlarged cavities of osteocytes between the oesteons is osteoid (Azan 1 80)



Figure 7 Spongiosation of the corticalis (HF 1 50)

py in these patients Among the 6 cases with complete therapeutical failures there were 2 patients who had taken sodium fluoride irregularly and had thus received too small doses This explanation, however, fails in the rest of the patients Obviously there exists a distinctly different response of the individual to fluoride This fact is known in the chronical industrial human fluorosis We observed two aluminium-smelters who had worked at the same place for 15 years, one of them suffered from fluorosis of stage III, the other from just beginning changes Which factors play a role in this process are not yet fully known, but Pandit et al (1940) found an increase in the fluoride effect in vitamin C deficiency and in malnutrition Kidney insufficiency also leads to an increased storage of fluorine in the body (Linsman & McMurray 1943, Havelka 1970) However, the ability of resorption of the gastrointestinal tract and the height of the kidney threshold for fluorine have a distinct influence on the intake of fluorine in bone The finding that there was frequently a reduction of the gastric acid in groups 3 and 4 leads to the conclusion that there is obviously a bad resorption of fluorine in a gastric acid deficiency In these cases a therapy of substitution with pepsin acid is perhaps indicated

There are three further problems

1 The combination therapy with calcium or anabolic steroids We combined the fluoride intake with calcium or anabolic steroids in a few patients A comparison of these groups, which were very small, with the patient groups which received NaF alone, showed no clear differences On the strength of our investigations we must reject the simultaneous intake of fluoride and calcium (Cohen et al 1969, Jowsey et al 1971) because insoluble calcium fluoride develops in the intestine which is absorbed with difficulty Ericsson (1971) therefore recommended a combination of sodium monofluorphosphate with complex fixed calcium A combination therapy with anabolic steroids seems to be recommendable
2 Since the publications of Larget (1952, 1960) it has been known that the storage of fluorine in the skeleton is reversible Roholm (1938) and Fritz (1958) found a regression of sclerosis in industrial fluorosis after the fluoride influence had stopped New investigations are necessary to find out whether one must go on giving continuous small doses of 5 to 10 mg NaF per day after the successful treatment or if an interval therapy with pauses of 4 to 12 weeks should be preferred

suffered from similar complaints After temporary reduction of the dose these pains disappeared and did not appear again later

In a woman we observed the following alarming side effect for a period of 14 months she received 30 to 40 mg, then, for a period of 12 months 20 mg sodium fluoride per day After these 2 years she developed a distinct hypaesthesia in both legs to the navel and in both arms to the elbows Apart from a slight peripheral ataxia, the reflex status was normal The neurologist diagnosed a sensible neuritis A toxical neuro-myelopathia could not be excluded The complaints, however, disappeared completely Whether the damage was due to the application of fluorine could not be discerned

DISCUSSION

The results of treatment of osteoporosis have not been satisfactory so far The therapy with sex hormones, introduced by Albright et al (1948), gave subjective alleviation of pain and positive nitrogen and calcium balances New bone formation, however, was found neither roentgenologically nor histologically (Jesserer 1953, Lafferty et al 1964, Reutter 1967, Rose 1967) With estrogens it is possible to reduce bone resorption only Similar results were obtained in the treatment with anabolic hormones (Wagner 1965, Rose 1967, Saville 1968, Kuhlencordt et al 1969, Jesserer 1970)

The administration of high doses of calcium propagated by Nordin (1962) was not sufficiently successful either, since an increase of the bone mass was not found (Lafferty et al 1964, Rose 1967, Reutter 1967, Kuhlencordt et al 1969, Jesserer 1970) Likewise, the therapy with vitamin D was disappointing (Jesserer 1953, Rose 1967 Reutter 1967)

The application of calcitonin (Milhaud et al 1969 Baud et al 1969) also only resulted in a reduced effect of bone resorption, whereas Jowsey et al (1971) and Bellwinkel et al (1971) observed even a negative effect The phosphonate-treatment proposed by Fleisch et al (1969) also seems to be unsuccessful (increase of the osteoid mass) according to Jowsey et al (1970)

By the NaF therapy of osteoporosis it was possible to demonstrate new bone formation roentgenologically as well as histologically for the first time

As has been previously shown, there were many cases with partly enthusiastic success, but nevertheless also a few therapeutical failures Therefore we studied intensively the causes of failure of fluoride thera-

ment was 12 to 42 months In spite of the relatively small doses of 20 to 60 mg sodium fluoride/d—as compared to those given in the literature—we obtained significant alleviation of pain or freedom from pain in ⅔ of the patients In the normal x-ray-picture some patients showed obvious remineralization In 18 out of 23 patients we were able to detect a strong increase of bone density by means of comparative densitometry of the thoraco-lumbal transition, a method we developed In 10 patients we performed repeated biopsies of the iliac crest Histologically there was clear evidence of an increase in bone mass We found a new formation of subperiostal fibrous bone and a formation of new bone on previously existing trabeculae The bone structure was only partly irregular spread osteoid seams were found by us only rarely We attribute the relatively rare atypical bone changes—in comparison to those given in the literature—to our small doses Employing histomorphometric methods (measuring of the average thickness of the trabeculae and determination of the volumetric bone density by means of point-counting volumetry) we could show an increase in thickness of the trabeculae from 50 to 70 μm and an increase in density of 16 per cent Furthermore, attention is given to the side effects and possible causes of complete failure of the sodium fluoride therapy in a number of patients (reduction in gastric acid)

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3 The slight increase of the serum calcium level could indicate an increased activity of parathyroid during the fluoride therapy In animal experiments (Faccini 1969, Franke 1971) there were also signs of a stimulation of parathyroid Cohen & Bernstein (1967) and Reutter et al (1970) demonstrated signs of hyperplasia of these glands during fluoride therapy However, we could not find radiological and biochemical signs of hyperparathyroidism in workers with industrial fluorosis, even in serious cases

Opponents of the fluoride treatment maintain, however, that newly formed bone is of poor quality The following reasons speak against that argument

1 As we have shown above, pathological changes of the newly formed bone are limitated with our small doses of 20 to 60 mg per day—a finding that was also made by Schenk et al (1970) in a patient after the reduction of the fluoride dose
2 In investigations on the breaking load on a fluorosis skeleton we (Franke et al 1972 b, Runge et al 1972) found a small diminution of the resistance to pressure in the isolated cylinders of the corticalis of femur in comparison to the normal bone However, the total lumbar vertebral body showed a resistance to pressure, which was three times higher
3 The determination of the absolute content of hydroxapatite showed in the femur neck in a patient with serious industrial fluorosis (stage III of Roholm) approximately a higher amount by three times 683 mg hydroxy apatite/ml bone in comparison to a normal content of 320 mg hydroxy apatite/ml bone (Rempel 1972)

Fluoride treatment does not necessarily result in replacement bone Some patients recorded that the complete load capacity of their skeleton was recovered after fluoride treatment Furthermore we believe that any new formation of bone even of inferior quality, is better than no formation at all

Nevertheless, each fluoride treatment of osteoporosis should be carried out under strict control of a specialist

SUMMARY

Since the end of 1969 we have treated 46 patients suffering from idiopathic osteoporosis with sodium fluoride The duration of the treat

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DIGITAL ANOMALIES INDUCED BY CYCLOPHOSPHAMIDE (ENDOXAN-ASTA) IN RAT FOETUSES

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Malformations of the limbs including digits have been produced experimentally in mammalian foetuses by using a variety of treatments during gestation, e g *X-irradiation* (Murphy & de Renyi 1930, Warkany & Schraffenberger 1947, Russell 1950, Hicks 1953, Neifach 1960, Murakami et al 1963, Nogami 1964), *nutritional deficiencies* (Warkany & Nelson 1941, Warkany & Schraffenberger 1943, Shepard et al 1968), *hypervitaminosis A* (Cohlan 1953, Kalter & Warkany 1961, Barrow & Rowland 1969), *hypoxia* (Ingalls et al 1950, Murakami et al 1962), *antitumour substances* (Haskin 1948, Murphy 1960, Endo & Abe 1965, Chaube & Murphy 1968, Singh & Sanyal 1972), *enzyme inhibitors* (Layton & Hallesy 1965, Wilson et al 1968, Scott 1970, Layton 1971); *alkaloids* (Courtney & Valerio 1968, Joneja & Ungthavorn 1969); *antihistamines* (King et al 1965, Wilk 1969), *thalidomide* (Fabro & Smith 1966 Nudleman & Travill 1971) The role of *mesoderm* vs its covering ectoderm in a growing limb bud has been investigated extensively to analyse the mechanism of limb morphogenesis (Harrison 1918, Detwiler 1929, Saunders 1948, Zwilling 1956, Goetinck 1964) Tschumi (1954) suggested that digits which differentiate first use up about the usual amount of mesoderm, consequently leaving an inadequate amount for the digits which differentiate later, in the event of mesenchymal insufficiency The order of mesenchymal condensation of digits in the hind limbs of *xenopus laevis* was found by Tschumi (1954, 1957) to be 4, 3, 5, 2 and 1 Forsthoefel (1963) found the order of differentiation of the toes of the mouse as 4, 5, 3, 2 and 1 Nogami (1964), while studying the frequency of malformations of the various digits of mice foetuses, induced by X-radiation, found digit 4 as the most resistant and hence least involved No systematic study of the digital morphogenesis in rat foetuses seems to have been reported The

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RESULTS

As seen from Table 1 the hands and feet showing abnormal digits were found only in the litters which received cyclophosphamide injections during the 12th to 14th days of gestation The foetuses from the control groups as well as from day 15 and 16 treated groups showed no digital abnormality The thirteenth day of gestation turned out to be the most sensitive period as the teratogenic assault on this day resulted in 76 per cent of abnormal hands and 92 per cent of abnormal feet (Figure 1) Although hands were significantly more affected than feet by treatment on the 12th day (i e 82 per cent vs 10 per cent $P < 0.001$) intervention on the 14th day resulted in reverse effect i e 2 per cent abnormal hands and 13 per cent abnormal feet ($P < 0.001$) Higher dosage of the drug on any particular day did not prove more suppressive for the developing digits in that group However higher doses proved more lethal as reported in our earlier studies (Singh 1971 Singh & Sanyal 1972) Although the affected hands and feet of the right and left sides did not show perfect symmetry the side differences were insignificant ($P > 0.70$ and $P > 0.90$)

The various types of digital anomalies (Figure 6) i e adactyly (absence of all digits) ectrodactyly (absence of one or more digits) syndactyly (fusion of digits) and brachydactyly (hypoplasia of digits) were found more frequently in the day 13 group than in other groups These anomalies were *significantly more* common in the hands than in the feet in the day 12 group ($P < 0.001$ Figures 2 and 3) but became

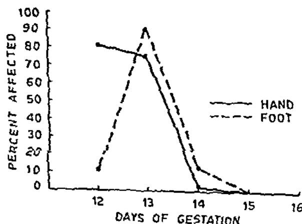


Figure 1 Hands and feet of rat foetuses having digital anomalies induced by maternal administration of cyclophosphamide on different days of gestation

present paper communicates the digital anomalies in rat foetuses induced by cyclophosphamide (an alkylating agent widely used clinically) given to pregnant rats during the 12th to the 16th day of gestation

MATERIALS AND METHODS

Wistar female rats weighing about 200 g obtained from the Institute for Research in Reproduction Bombay, were kept under standard conditions and mated in oestrus with the males of the same strain by placing them overnight in individual cages The following day was counted as day zero of the pregnancy if sperms were *found in* the vaginal smears Freshly prepared solution of the cyclophosphamide (Endoxan Asta manufactured by Khandelwal Laboratories Private Ltd Bombay) in normal saline was administered by single intraperitoneal injection (I P) to pregnant rats on days 12–16 of gestation (Table 1) Dosage of the drug was worked out on the basis of mg/kg of the body weight of the pregnant animal at the time of the injection Control rats received the same volume of the saline without the drug during corresponding gestation periods

All females were killed on day 21 of gestation the abdominal wall was opened and both uterine horns were exteriorised The number and position of live dead and resorbed foetuses were noted Surviving foetuses were removed after uterotomy *examined for gross malformations and preserved in fixatives Hands and feet were* later rechecked under the binocular dissecting microscope and details of various digital anomalies recorded The gestation period in a few experimental rats was prolonged for 2 days by injections of progesterone (on the lines of Barrow & Rowland 1969) to see if with further development the digital anomalies became more conspicuous

Table 1 Incidence of malformations of hands and feet in the rat foetuses following maternal administration of cyclophosphamide on different days of gestation

Days of treatment	Dose/kg	No of litters	No of implants	No of resorptions	No of hands examined	Abnormal hands (%)	No of feet examined	Abnormal feet (%)
12th	8 15 mg	22	181	94	168	*137 (81 5%)	168	17 (10 1%)
13th	10 18 mg	19	164	11	300	227 (75 6%)	300	276 (92 0%)
14th	12 20 mg	24	202	10	380	§9 (2 3%)	380	48 (12 6%)
15th	15 20 mg	14	92		184		184	–
16th	20–30 mg	10	88	1	174		174	
Control	Saline	*10*	*130*		*200*	–	200	
Total		105	857	116	1466	373 (25 4%)	1466	341 (23 2%)

* $P < 0.001$ when compared with those of feet in the 12th day group

§ $P < 0.001$ when compared with those of feet in the 14th day group

RESULTS

As seen from Table 1, the hands and feet showing abnormal digits were found only in the litters which received cyclophosphamide injections during the 12th to 14th days of gestation The foetuses from the control groups as well as from day 15 and 16 treated groups showed no digital abnormality The thirteenth day of gestation turned out to be the most sensitive period as the teratogenic assault on this day resulted in 76 per cent of abnormal hands and 92 per cent of abnormal feet (Figure 1) Although hands were significantly more affected than feet by treatment on the 12th day (i e 82 per cent vs 10 per cent, $P < 0\ 001$), intervention on the 14th day resulted in reverse effect, i e 2 per cent abnormal hands and 13 per cent abnormal feet ($P < 0\ 001$) Higher dosage of the drug on any particular day did not prove more suppressive for the developing digits in that group However, higher doses proved more lethal as reported in our earlier studies (Singh 1971, Singh & Sanyal 1972) Although the affected hands and feet of the right and left sides did not show perfect symmetry, the side differences were insignificant ($P > 0\ 70$ and $P > 0\ 90$)

The various types of digital anomalies (Figure 6), i e adactyly (absence of all digits), ectrodactyly (absence of one or more digits), syndactyly (fusion of digits) and brachydactyly (hypoplasia of digits) were found more frequently in the day 13 group than in other groups These anomalies were significantly more common in the hands than in the feet in the day 12 group ($P < 0\ 001$ Figures 2 and 3) but became

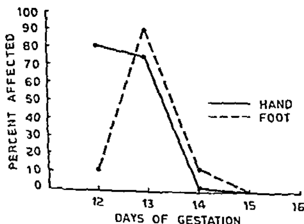


Figure 1 Hands and feet of rat foetuses having digital anomalies induced by maternal administration of cyclophosphamide on different days of gestation

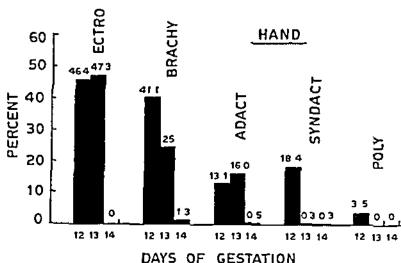


Figure 2 Various types of digital malformations in hands of rat foetuses induced by maternal administration of cyclophosphamide on different days of gestation

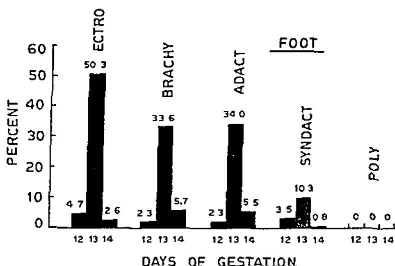


Figure 3 Various types of digital malformations in feet of rat foetuses induced by maternal administration of cyclophosphamide on different days of gestation

predominant in the feet in the group treated on the 13th day of gestation ($P < 0\ 05$ to $P < 0\ 001$) In the day 14 group brachydactyly and adactyly were significantly more common in the feet ($P < 0\ 01$ and $P < 0\ 001$) but the increase in the incidence of ectrodactyly and syndactyly was not significant ($P > 0\ 30$ and $P > 0\ 95$) Polydactyly (extra digit) was however found in the hands only and that also was confined to the group treated on the 12th day of gestation (Figure 2) All such hands showing polydactyly also exhibited syndactyly of some

digits (Figure 6 B) Pedunculated digit was occasionally seen in the toes in the day 13 group (Figure 6 H) Syndactyly in the hands was also practically confined to the day 12 group (Figure 2) and was more frequently seen than that of the feet (Figure 3) in this group (18 per cent vs 4 per cent, $P < 0.001$) Ectrodactyly was the commonest anomaly observed in the hands and feet and its incidence was a maximum in the day 13 group (47 per cent and 50 per cent respectively—Figures 2 and 3) Hypoplasia of the digits next in order of frequency was also more common in the day 13 group when digits of hands and feet were considered together (25 per cent and 34 per cent in the hands and feet respectively) No ectrodactyly was seen in any hands of the day 14 group whereas the feet showed it in 3 per cent of cases However, in the day 12 group, ectrodactyly was more common in the hands than in the feet (46 per cent vs 5 per cent $P < 0.001$, Figures 2 and 3) All kinds of digital deformities were found to be more common in hands than in feet in the day 12 group (the incidence varying from 4 per cent to 46 per cent), while in the day 14 group the incidence of various types of digital anomalies of the hands as well as feet was markedly reduced (varying from 0 per cent to 6 per cent) Different types of anomalies existed in conjunction with each other in the affected hands and feet and manifested themselves in various transitional forms Sometimes only rudimentary nodules (1 3) were seen at the distal end of the limbs (Figures 6 I and J)

Involvement of the individual digits in the hands and feet in the various groups are shown in Figures 4 and 5 As at times it was difficult to identify the individual digits without proper skeletal visualization, especially when only one digit was present, the findings were checked by the double blind method Both in the hands and the feet, the third digit was found to be least commonly affected ($P < 0.01$ and $P < 0.001$ respectively) whereas the first and the fifth digits were most commonly involved (Figure 5) Taking the missing and rudimentary digits together the suppression of digits occurred in the order of 1, 5, 2, 4, 3 digits in the hands and 1 5 4, 2, 3 digits in the feet (Figure 4) Fusion of the digits was most commonly observed between the second and the third digits both in the hands and the feet The first digit was not fused with the second digit in any hand or foot This pattern of individual digital involvement was observed to be more or less the same in all the three groups showing digital deformities

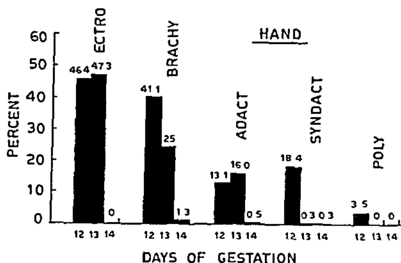


Figure 2 Various types of digital malformations in hands of rat foetuses induced by maternal administration of cyclophosphamide on different days of gestation

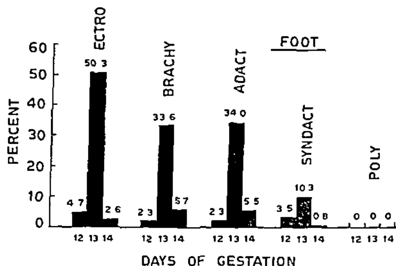
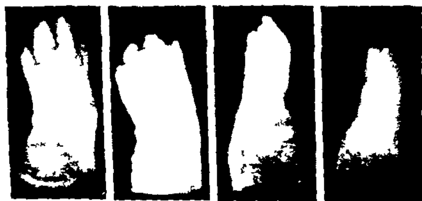
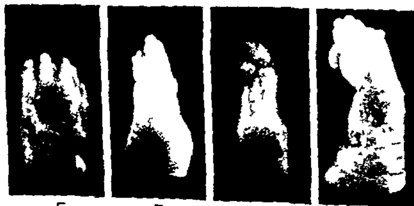
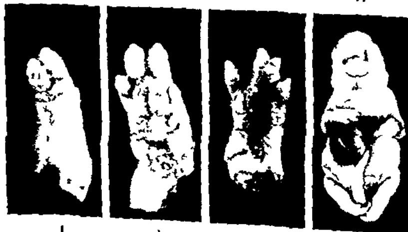


Figure 3 Various types of digital malformations in feet of rat foetuses induced by maternal administration of cyclophosphamide on different days of gestation

predominant in the feet in the group treated on the 13th day of gestation ($P < 0.05$ to $P < 0.001$) In the day 14 group, brachydactyly and adactyly were significantly more common in the feet ($P < 0.01$ and $P < 0.001$) but the increase in the incidence of ectrodactyly and syndactyly was not significant ($P > 0.30$ and $P > 0.95$) Polydactyly (extra digit) was, however, found in the hands only and that also was confined to the group treated on the 12th day of gestation (Figure 2) All such hands showing polydactyly also exhibited syndactyly of some


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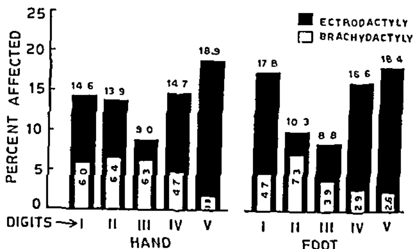


Figure 4 Incidence of ectrodactyly and brachydactyly in individual digits of rat foetuses induced by single I P injection of cyclophosphamide given to pregnant rats on the 12th–14th day of gestation

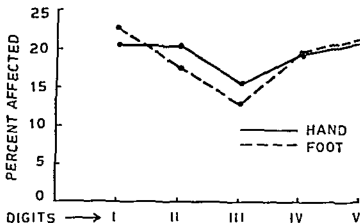


Figure 5 Susceptibility of individual digits of rat foetuses to the teratogenic action of single I P injection of cyclophosphamide given to pregnant rats on the 12th–14th day of gestation

Figure 6 Involvement of the digits in 21 day old rat foetuses after single I P injection of cyclophosphamide given to pregnant rats on the 12th 14th day of gestation A (Control) Hand (Lt) normal (thumb not visible) B (8 mg/12th day) Hand (Lt) showing syndactyly and polydactyly (thumb not visible) C (8 mg/12th day) Hand showing ectrodactyly and brachydactyly, D (15 mg/13th day) Hand showing adactyly E (Control) Foot normal (Rt) F (15 mg/13th day) Foot showing ectrodactyly and brachydactyly and syndactyly G (15 mg/13th day) Foot showing ectrodactyly brachydactyly and a rudimentary nodule H (15 mg/13th day) Foot showing ectrodactyly and pedunculated and deviated great toe I (15 mg/13th day) Hand showing ectrodactyly brachydactyly rudimentary nodule (Palmar view), J (15 mg/13th day) Foot showing ectrodactyly brachydactyly and rudimentary nodule (Planter view) K (12 mg/12th day) Foot of 23 day old foetus (progesterone treated) showing ectrodactyly and syndactyly L (15 mg/13th day) 21 day old foetus showing digital anomalies of hands and feet besides other anomalies

are acting in the same gestation period (Cahen 1964)? The results of teratogenicity further depend not only on the species of the animals used but also on the strain of the animal Nogami (1964) found the digital malformations varying in total number and even in kind in two strains of mouse foetuses treated by X-radiation under similar experimental conditions However, the critical period of vulnerability and the type of digital malformations induced by cyclophosphamide in rats in the present study closely resemble those of mice caused by X irradiation The X irradiation probably causes a cellular necrosis of the digital primordia (Murakami et al 1963) Cyclophosphamide (a radiomimetic drug) is first activated in the liver of the host, resulting in liberation of its alkylating radical (Brock 1967) which is highly reactive and its major action seems to be related to the inhibition of deoxyribonucleic acid (DNA) The prolonged inhibition of DNA synthesis may lead to localised cell death sufficient to upset proliferative rates within the organs, resulting in malformations (Ritter et al 1971) The teratogenic actions of cyclophosphamide (Chaube et al 1967, Singh 1971) nitrogen mustard (the parent alkylating agent—Haskin 1948) and X radiation (Russell 1954, Nogami 1964) have shown striking similarities, possibly because of their similar mode of action, i e inhibition of DNA synthesis The brunt of the damage caused by these agents is however, borne mainly by the mesenchymal tissue (Hicks et al 1957, Murphy et al 1958, Neifach 1960, Greenberg & Tanaka 1964, Singh et al 1971)

The various digital anomalies (adactyly, ectrodactyly, syndactyly, brachydactyly, etc) are manifestations of the injurious effect of the teratogen on the proliferating and differentiating mesenchymal tissue in the regions of hands and feet Nogami (1964) found that a higher dose of X [illegible]

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DISCUSSION

While studying digital anomalies of mouse foetuses induced by X-radiation, Nogami (1964) found the 12th day to be the most sensitive period, which corresponded with the findings of Russell (1950, 1954) who had observed a similar critical period for digital anomalies in mice Neifach (1960) and Gebhardt (1970) also found the period between the 11th and 12th day of gestation to be more sensitive for the production of digital anomalies in mice The limb bud of the rat lags behind that of mice by a period of 1½ days in its appearance and further differentiation (Ihara 1970) The critical period when developing digits in rat foetuses are most vulnerable to any teratogenic assault as observed in the present study (i e 13th day) is thus identical with that observed in mice Since all parts of the embryo are not fashioned simultaneously but emerge in their due succession and order, under the influence of organisers, the brunt of the disturbance is borne chiefly by the tissue or organ which is undergoing a rapid phase of development at the time when such an interference occurs In fact each developing organ or part passes through an individual critical period during which it is undergoing accelerated growth and differentiation, and manifests marked susceptibility to the injurious influences brought to bear on it Other parts may or may not be so scheduled as to be sensitive at that particular moment to those particular influences Since the forelimb buds appear a day earlier than the hind limb buds in rats Edwards 1968) as well as in mice (Rugh 1968), intervention during early gestation period (12th day) affected digital anomalies of the hand more than those of the feet, as the latter were not passing through their critical stages of proliferation and differentiation at the time This occurred about a day later, i e on the 13th day, when maximum digital anomalies of feet resulted A similar sequence of digital involvement has been reported by Kreybig (1968) and Gebhardt (1970) As the critical phase of differentiation of the digits was over, administration of the drug on the 15th and 16th days of gestation did not induce any digital anomaly (Table 1) However, development of anomalies is not only dependent on the critical stage as was thought earlier (Stockard 1921, Asling et al 1955) but the tissues also show differential susceptibility according to the agent employed (Nishimura 1959) Why, for example, does the thalidomide drug pick up only the mesenchymal tissue and cortisone induces mainly facial anomalies while rubella infection and other teratogenic agents have no similar effect, when all

are acting in the same gestation period (Cahen 1964)? The results of teratogenicity further depend not only on the species of the animals used but also on the strain of the animal Nogami (1964) found the digital malformations varying in total number and even in kind in two strains of mouse foetuses treated by X radiation under similar experimental conditions However, the critical period of vulnerability and the type of digital malformations induced by cyclophosphamide in rats in the present study closely resemble those of mice caused by X irradiation The X irradiation probably causes a cellular necrosis of the digital primordia (Murakami et al 1963) Cyclophosphamide (a radiomimetic drug) is first activated in the liver of the host, resulting in liberation of its alkylating radical (Brock 1967) which is highly reactive and its major action seems to be related to the inhibition of deoxyribonucleic acid (DNA) The prolonged inhibition of DNA synthesis may lead to localised cell death sufficient to upset proliferative rates within the organs, resulting in malformations (Ritter et al 1971) The teratogenic actions of cyclophosphamide (Chaube et al 1967, Singh 1971) nitrogen mustard (the parent alkylating agent—Haskin 1948) and X radiation (Russell 1954, Nogami 1964) have shown striking similarities possibly because of their similar mode of action, i e inhibition of DNA synthesis The brunt of the damage caused by these agents is, however, borne mainly by the mesenchymal tissue (Hicks et al 1957, Murphy et al 1958, Neifach 1960, Greenberg & Tanaka 1964, Singh et al 1971)

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to Grüneberg (1961) the blastema for digits 2 to 4 seem to be laid down first and both marginal rays follow later This may account for the higher frequency of involvement of digits 1 and 5 Muto (1970) also observed digit 5 of the forelimb of toad larva to be most commonly involved in teratological experiments and found it difficult to explain on the hypothesis of Tschumi (1954) Further, brachydactylism may not be due to shortening of the metatarsals but may result from hypophalangism alone (Muto 1969) The phalanges of digit 3 were found to be most resistant by Muto (1971) which could explain the least involvement of digit 3 in our study Systematic study of the order of blastemal condensation of various digits in rats and their order of chondrification and ossification may throw more light on the morphogenesis of digits

SUMMARY

Single intraperitoneal injections of cyclophosphamide (endoxan-asta) administered to pregnant rats on the 12th–14th day of gestation resulted in a variety of malformations of the digits of the foetuses collected on day 21 No digital anomaly was detected in the control group or in the groups treated on the 15th and 16th days of gestation Dose response relation could not be established for any type of digital malformation on any day of treatment Digits of the hands were most frequently involved in the day 12 group (82 per cent) as compared to those of feet (10 per cent) Treatment on the 14th day of gestation affected more toes (13 per cent) than fingers (2 per cent) The thirteenth day of gestation was found most susceptible for induction of digital anomalies and it affected 92 per cent of feet and 76 per cent of hands Polydactyly occurred exclusively in the hands and only in the 12 day group Syndactyly most commonly affected the digits 2 and 3 both in the hands and feet Ectrodactyly and brachydactyly, the commonest digital anomalies mainly involved digits 1 and 5 in both limbs The antimitotic action of cyclophosphamide mostly suppressed the mesenchymal blastema destined for the marginal digits (1 and 5) resulting in hypoplasia or disappearance of these digits Digit 3 was found to be most resistant to its teratogenic effects

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the commonest type of anomaly seen amongst the malformed hands and feet The antimitotic activity of cyclophosphamide led to a diminished amount of the mesenchyme which was not sufficient for the differentiation of all the digits thus resulting in absence of one or more digits In such mesenchymal insufficiency the digits which differentiate first, use up the normal amount of mesenchyme leaving little or none for the digits differentiating relatively later (Tschumi 1954) If the amount of mesenchyme left is small, the digits differentiating later may remain united (syndactyly) and if no mesenchyme is left these may not differentiate at all and disappear (ectrodactyly) Polydactyly occurred only in the hands (3 5 per cent) and in the group treated on 12th day alone All such cases showed syndactyly also (Figure 6) Nogami (1964) found polydactyly in mice occurring only in the feet and it appeared a little earlier than the syndactyly which was not associated with it The critical stage for the induction of polydactyly has been found to precede the one for other digital anomalies, not only in mammals (Gebhardt 1970), but also in amphibia (Gebhardt & Faber 1966) No satisfactory explanation, however, seems available for this phenomenon

The order of mesenchymal condensation of digits in the hind limbs of *xenopus laevis* was found by Tschumi (1954, 1957) to be 4, 3, 5, 2, 1 and Forsthoefel (1963) *found the order of differentiation* of the toes of the mouse as 4, 5, 3, 2, 1 As the digits on the preaxial border, i e 2 & 1, differentiate last of all, these are commonly affected, resulting in syndactyly or ectrodactyly The digit 4 which is thus first to differentiate *has been found to be usually most resistant to the teratological* insults (Nogami 1964, Muto 1971) However, Maeda (1970) did not find any consistency in such a resistance because it varied with the stage of development of the digits when the teratogen was administered *In the hands, he found the digit 2 was most resistant when treatment* was given on the 10th day of gestation, but in the day 11 group digit 1 was least involved On the 12th day, digit 4 was least affected while on the 13th day, digit 2 was equally resistant In our present study digit 3 *was found to be least involved in the hands* ($P < 0.01$) as well as in the feet ($P < 0.001$) The order of suppression of digits was noted as 1, 5, 2, 4, 3 in the hands and 1, 5, 4, 2, 3 in the feet Nogami (1964) also found a different order of suppression in the fingers and toes of mice This is *also in line with the findings of* Maeda (1970) who found digits 1 and 5 to be more commonly affected both in the hands and feet in the group of rats treated on the 13th day of gestation According

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THE VALUE OF HISTOLOGY, CULTURE AND GUINEA PIG INOCULATION EXAMINATION IN OSTEO-ARTICULAR TUBERCULOSIS

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Tuberculosis is on the decline in affluent countries, but in developing countries it remains one of the major public health problems Osteo articular tuberculosis in economically underdeveloped countries of the world remains one of the main conditions to be dealt with in any orthopaedic centre About 7 5 per cent of the total cases attending the outpatient services of the Orthopaedic Department of the Institute of Medical Sciences, Banaras Hindu University, were those of osteo-articular tuberculosis (Tuli et al 1967)

Availability of effective anti-tubercular drugs has made the treatment of this condition relatively simple and safe provided the diagnosis is accurately made Clinical and radiological methods which are adopted to diagnose this condition are not always accurate, as many conditions may mimic tuberculosis clinically and radiologically At the same time osteo-articular tuberculosis does not always present a typical clinical and radiological picture, thus some lesions can be missed The diagnosis can be accurately established by submitting the material from the suspected lesions for histological examination and/or culture and/or guinea pig inoculation However, histology alone does not confirm the diagnosis in all cases as the anti tubercular drugs are now known to change the histological pattern of tuberculous tissue (Wilkinson & Notley 1953) To prove the diagnosis of tuberculosis, ideally speaking, the causative organism must be recovered from the lesion

In the present work an attempt has been made to correlate clinical and radiological observations with those of histological findings and microbiological findings for *Mycobacterium tuberculosis*

METHODS AND MATERIAL

To establish the diagnosis of osteo articular tuberculosis we studied the material of 105 cases who attended the Orthopaedic Department of the Institute of Medical Sciences Banaras Hindu University during the period from May 1969 to July 1970 Only those cases were included in this study who could provide material such as pus granulation tissue or curettings from sinus walls or abscess cavities or material during surgical excisions of diseased tissue for investigation The material available was subjected to histological examination and/or culture and/or guinea pig inoculation Of the 105 cases studied 43 patients gave history of treatment by antitubercular drugs mostly irregularly for a period varying between three months and one year Lowenstein Jensen medium was used for culture

Material subjected to culture

All the 105 samples from 105 lesions were subjected to culture In 36 cases where both pus and granulation tissue were available granulation tissue was subjected to histological examination whereas pus was used for cultural and guinea pig inoculation

OBSERVATIONS

Table 1 Analysis of results of culture

Total no subjected	Positive	Negative	Contaminated
105	52	31	22
100	49 53 %	29 5 %	20 95 %

Culture

At the end of 20 weeks cultures were positive in 52 (49 52 per cent) cases 31 (29 5 per cent) cultures were negative 22 (20 95 per cent) became contaminated The conventional period for growing acid fast bacilli is eight weeks at the most However, observations were made for 20 weeks in the present series Visible colonies appeared in 27 per cent of the positive cultures on incubation beyond 8 weeks Findings are summarized in Table 1

Histopathological observation

Fifty five samples (from 105 lesions) were subjected to histological examination 40 (72 72 per cent) of which were diagnosed as tuberculous 11 (20 per cent) as of chronic non specific inflammation and one (1 81 per cent) as chronic eosinophilic granuloma (Table 2) Three (5 45 per cent) cases were subjected to histological examination twice

Table 2 Analysis of histological findings in 55 cases

Total no subjected	Diagnosis tuberculosis	Diagnosis non specific chronic inflammation	First diagnosis tuberculosis, 2nd diagnosis chronic inflammation	Other diagnosis chr eosinophil granuloma
55 100 %	40 72 77 %	11 20 %	3 5 45 %	1 1 %

The first diagnosis was tuberculosis Repeat samples, when examined after eight months of anti-tubercular therapy, were found to have chronic inflammatory change with no evidence of tuberculosis

Table 3 Analysis of results of guinea pig inoculation in 56 samples

Total no subjected	Positive	Negative	Died of intercurrent infection
56 100 %	40 71 43 %	10 17 86 %	6 10 71 %

Guinea pig inoculation

As summarised in Table 3, guinea pig inoculation was done in 56 cases The result was positive for tuberculosis in 40 (71 43 per cent), 10 (17 86 per cent) were negative and six (10 71 per cent) died of intercurrent infections

Proof of tuberculosis

Diagnosis of tuberculous infection was considered proven if there was positive evidence of tuberculosis in histopathology or on culture or on guinea pig inoculation As shown in Table 4, the diagnosis of tuberculosis was proven in the present series in 84 (80 per cent) out of 105 cases who were suspected to have tuberculosis on a clinical and radiological basis Histology and culture and guinea pig inoculation were positive for tuberculosis in 11 cases only Positive histology and culture were found in 8 cases only Culture and guinea pig inoculation were found positive in 9 cases In another 9 cases diagnosis was proven by guinea pig inoculation and histological examination Histological proof alone was positive in 12 cases only culture was positive in 24

Table 4 Analysis of material showing incidence of proof of tuberculosis in 105 lesions

Sl No	Diagnosis proved by	No of cases	Total	Total percentage
1	Positive histology + culture	8	84	80 %
2	Positive histology + culture + guinea pig inoculation	11		
3	Positive culture + guinea pig inoculation	9		
4	Positive histology + guinea pig inoculation	9		
5	Positive histology only	12		
6	Positive culture only	24		
7	Positive guinea pig inoculation only	11		
8	Negative by culture and/or by histology and/or guinea pig inoculation	21	21	20 %

cases and diagnosis was solely made by guinea pig inoculation in 11 cases In 21 cases the diagnosis of tuberculosis was only on the basis of clinical and radiological findings, histology, culture and guinea pig inoculation results were nonconfirmatory

DISCUSSION

Cultures

Dobson (1951) Dahl (1951), Wilkinson & Notley (1953) and Hald, Jr (1964) got higher percentages (approximately 70 80) of positive cultures because their patients did not have antitubercular drugs before investigations were done In the present work tuberculosis was proven in 49 52 per cent of 105 cases subjected to culture If con taminated cultures were excluded the percentage of positive cultures in the present series was 62 65 per cent

Use of anti tubercular drugs before submitting material for culture may be responsible for lower incidence of positive culture in the present study

Value of histology

Even before the availability of anti tubercular drugs the histological proof of tuberculosis was not forthcoming in all cases [illegible]

[illegible] Barr 1936

Table 2 Analysis of histological findings in 55 cases

Total no subjected	Diagnosis tuberculosis	Diagnosis non specific chronic inflammation	First diagnosis tuberculosis 2nd diagnosis chronic inflammation	Other diagnosis chr eosinophil granuloma
55 100 %	40 72 77 %	11 20 %	3 5 45 %	1 1 %

The first diagnosis was tuberculosis Repeat samples, when examined after eight months of anti-tubercular therapy, were found to have chronic inflammatory change with no evidence of tuberculosis

Table 3 Analysis of results of guinea pig inoculation in 56 samples

Total no subjected	Positive	Negative	Died of intercurrent infection
56 100 %	40 71 43 %	10 17 86 %	6 10 71 %

Guinea pig inoculation

As summarised in Table 3, guinea pig inoculation was done in 56 cases The result was positive for tuberculosis in 40 (71 43 per cent), 10 (17 86 per cent) were negative and six (10 71 per cent) died of intercurrent infections

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Use of anti tubercular drugs before submitting material for culture may be responsible for lower incidence of positive culture in the present study

Value of histology

Even before the availability of anti tubercular drugs the histological proof of tuberculosis was *not forthcoming* in all cases Average histological proof of tuberculosis in skeletal lesions in the pre antitubercular era has been reported to be 76 56 *per cent* (Swift 1936, Barr 1936

Brodin 1951, Yu 1951) The percentage of histological positivity does not seem to have altered appreciably in the era of specific anti-tubercular drugs The average reported in the post antitubercular era is 74 37 per cent (Wilkinson 1955, Paus 1964, Hald, Jr 1964) In the present study 55 cases were subjected to histological examination and proof of tuberculosis was available in 72 73 per cent of cases

Guinea pig inoculation

In the present work guinea pig inoculation was positive in 71 53 per cent of cases submitted for this investigation In general our findings of guinea pig inoculation are in agreement with the observations of many other workers such as Swift (1936), Guri (1947) and Yu (1951)

Histology and culture

Kondo (1957), Paus (1964), and Hald, Jr (1964) reported proof of skeletal tuberculosis in about 73 to 80 per cent of cases by combining histology and culture In the present work the proof of tuberculosis was available in 89 09 per cent of 55 cases submitted for combined investigations Thus if material from cases of osteo-articular tuberculosis is subjected simultaneously to culture and histological study, diagnosis can be proven in about 74 to 89 per cent of the cases

Culture and guinea pig inoculation

We failed to get any literature on culture and guinea pig inoculation study in osteo-articular tuberculosis In our study tuberculous nature of the lesion could be proven in about 89 29 per cent cases when material was cultured and inoculated into the guinea pigs Culture and guinea pig inoculation together gave almost similar percentages of positively as that obtained by culture and histology

Histology and culture and guinea pig inoculation

Material from 28 cases was simultaneously submitted for histological examination, culture and guinea pig inoculation The diagnosis of tuberculosis by combining the results of these investigations was proven in 100 per cent of the cases It seems that if material and facilities are available to conduct histological investigations, culture and guinea pig inoculation in a particular case, there is a 100 per cent chance of getting the proof of tuberculosis

Proof of tuberculosis

Cleveland (1955), Ahlberg (1948), Brodin (1951), Weinberg (1957) and McNeur (1955) reported proof of tuberculosis in about 77 to 92 per cent of the cases by histology and/or culture and/or by guinea pig inoculation In the present series proof of skeletal tuberculosis was available in 80 per cent of the cases by histology and/or by culture and/or by guinea pig inoculation Thus, in conclusion when material was subjected to histology and/or culture and/or guinea pig inoculation, diagnosis in skeletal tuberculosis could be proven in 76 to 91 per cent cases

Best investigation to prove diagnosis

Histological proof of tuberculosis was available in 72 72 per cent of the cases in the submitted series, whereas disease was proven by culture in 49.52 per cent Obviously disease was proven histologically in a greater number of cases than by culture But in 50 per cent of the cases found histologically negative, cultures were positive for *Mycobacterium tuberculosis* It seems that in histologically negative cases, culture may be positive in an appreciable percentage In comparison to culture, guinea pig inoculation yielded better results Thus it may be concluded that guinea pig inoculation as a single investigation was the best method for establishing diagnosis of osteo-articular tuberculosis, if material is not available for a combination of histological and microbiological investigations and guinea pig inoculation simultaneously

SUMMARY AND CONCLUSION

Proof of tuberculosis was available by positive culture in 62 55 per cent of the cases after excluding contaminated cultures Of the cases subjected to histological examination 72 72 per cent were reported as tuberculous 11 cases had evidence of chronic inflammatory change, but 50 per cent of these had positive culture for *Mycobacterium tuberculosis* One case reported as eosinophilic granuloma histologically was proven to be tuberculous by culture

Guinea pig inoculation yielded the proof of tuberculosis in 71 43 per cent of cases, when material was subjected simultaneously to histological examination and culture and guinea pig inoculation the proof of tuberculosis was obtained in 100 per cent of the cases

It is suggested that all infective lesions and lesions of doubtful

etiology in the osteo articular system should be submitted for microbiological examination (for acid fast bacilli and pyogenic organism), guinea pig inoculation and for histopathology for arriving at the final diagnosis

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AN ANTERIOR, EXTRAPHARYNGEAL, SUPRAHYOID APPROACH TO THE FIRST, SECOND AND THIRD CERVICAL VERTEBRAE

JAMES W G MURRAY & R JAMES SEYMOUR

Accepted 10 iv 73

When faced with the problem of approaching the anterior aspect of the first second and third cervical vertebrae, the surgical literature to date presents an array of formidable procedures The approach of Fang & Ong (1962) and Hodgson & Stock (1956, 1960) through the pharyngeal cavity was felt to increase the risk of infection beyond reasonable limits in this case The approach of Foille & Delmas, well described and illustrated by Kaplan (1966), approaching the first three cervical vertebrae, in effect laterally, requires an approach proceeding around a considerable number of vital structures, namely the seventh, tenth, eleventh and twelfth cranial nerves, and the second, third and fourth cervical nerves, the branches of the internal jugular vein and the external carotid artery Similarly, the approach of DeAndrade & McNab (1967, 1969) also approaches the cervical vertebrae laterally In their later series of five cases they indicated that tracheostomy was necessary in four out of five patients They described encountering the accessory nerve, the hypoglossal nerve and dividing the superior thyroid, lingual and facial arteries and accompanying veins in order to obtain access to the retropharyngeal space The traction effect on the pharyngeal and laryngeal branches of the vagus nerve were also described

CASE REPORT

The procedure which we are about to describe was performed in the case of a 23 year old graduate university student who presented with X rays demonstrating a fracture dislocation of C 2 on C-3 with marked displacement of C-2 anteriorly Fractures of the lamina and pedicles were present The sole neurologic deficit present was transient paresthesias in one arm The patient was placed in Vinke tongs, and a closed reduction of the fracture was performed under X ray control with the patient awake Fractures of the right second third fourth fifth and eighth ribs and a pneumonic process in the right middle lobe and a pneumothorax necessitated

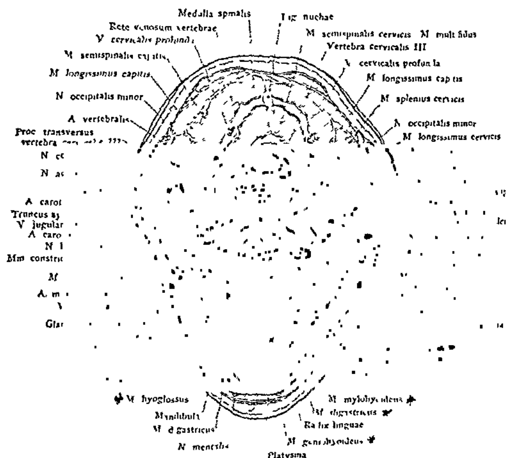


Figure 1 A cross-section of the neck through the point of the chin. Singly starred structures must be divided The division of these structures and the rotation of the neck 45° opens the extrapharyngeal plane to the anterior aspect of the vertebral bodies

continuation of a conservative course for a period of 3½ weeks During this time the fracture dislocation was found to be extremely unstable, tending to displace anteriorly In addition, the patient commenced to develop pressure sores over his occiput, which with the comminution of the posterior elements presented us with no choice but to fuse the second and third cervical vertebrae anteriorly

At surgery the patient evidenced a tear of the anterior longitudinal ligament with displacement of the disc material beneath this, and destruction of the C-2–C-3 disc space This was felt to contribute in part to the anterior displacement However it was felt that the site of the fracture, plus the absence of any posterior attachments was responsible primarily for the instability At surgery slight residual displacement of the second cervical vertebra was found with reference to the third

Prior to performing the operative procedure, with the patient awake, and prior to being anesthetized, his neck was gently extended 20° and then rotated as far to the left as comfortably possible, approximately 45° When no neurologic symptoms were produced, the patient was anesthetized and intubated A transverse incision was made on the right along the upper border of the hyoid from just lateral to the

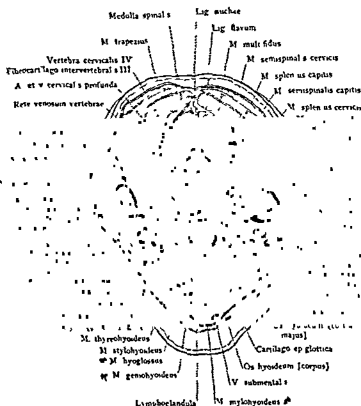


Figure 2 Cross section of the neck passing through the hyoid bone The singly starred structures were divided

midline toward the sternocleidomastoid The skin and platysma were incised The external cervical fascia was divided parallel to the skin incision The hyoid was exposed along its superior margin The capsule about the submaxillary gland was divided and the gland retracted cephalad Care must be taken to avoid perforating the gland The anterior portion of the digastricus muscle was then divided, further facilitating exposure The lingual artery was identified and divided and ligated. This step facilitates maintenance of a dry field The hypoglossal nerve next comes into view in the layer beneath the digastricus muscle and deep to the mylohyoideus muscle It is usually picked up between the mylohyoideus and the hyoglossus muscles Once the hypoglossal nerve has been identified, care must be taken in its retraction in a cephalad direction The patient experienced transitory ipsilateral tongue paresis postoperatively, in the absence of vigorous retraction in this case Three muscles remaining in the way required incision, namely the mylohyoideus extending from the mandible to the anterior surface of the hyoid bone, the hyoglossus extending from the upper border of the greater cornu of the hyoid bone and adjacent body to the base of the tongue, and the genioglossus fanning from the



Figure 3 Initial lateral X ray of the fracture dislocation of C 2 on C 3





Figure 4 Lateral X ray of the cervical spine at a later date demonstrating the instability of the fracture at this level

spine of the mandible toward the tongue and the medial part of the superior border of the hyoid bone Once these three muscles were incised the extrapharyngeal plane lying medial to all of the neurovascular structures heretofore encountered in other exposures and extending extrapharyngeally to the ventral surface of the vertebral bodies of the upper three cervical vertebrae was opened

This plane was dissected bluntly The rotation of the neck tended to rotate the pharynx away from the neurovascular structures The interval between the pharynx and the longus colli muscle was readily developed in the exact midline of the vertebra contributing to the avoidance of bleeding at this point At this point in the procedure the disc space was identified radiographically We found it easy to insert a needle at the C-3–C 4 disc space The exposure was found to be readily obtained from the anterior portion of the first cervical vertebra distally to that of



Figure 5 Operative X ray showing placement of the marker needle at C 3 C-4 disc level

the fourth cervical vertebra Periosteal stripping of the longus colli and longus capitus muscles facilitated exposure of the appropriate vertebrae and disc space We felt there was adequate space for the use of most neurosurgical instruments, including the smaller Cloward (1958) instruments if necessary, at the C-2–C-3 level We found it possible to remove the disc and perform a fusion without the necessity of resorting to these instruments The wound was closed by simply approximating the platysma and skin Bleeding was negligible, and a drain was not necessary

Postoperatively the patient was kept in Vinke tongs for a period of six weeks, at which time X rays showed incorporation of the graft and adequate progress of the fusion The patient was then placed in a four poster brace, and permitted to sit up in bed and to ambulate gradually The patient had no neurologic deficit save for a problem with balance at the time of discharge This was felt related to his extensive period of recumbency, though the possibility of vertebral artery trauma at the time of the original injury was entertained However, the balance problem disappeared with time

On follow up four years later, the patient is now leading a normal life, is married, and is teaching He has 90° of neck rotation to the right and to the left, and flexion such that he touches his chin to his chest, and extension of 20°

DISCUSSION

The anter[illegible]

[illegible] because of the limitations incurred by the superior



Figure 3 Initial lateral X-ray of the fracture dislocation of C-2 on C 3



Figure 4 Lateral X ray of the cervical spine at a later date, demonstrating the instability of the fracture at this level

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On follow up four years later the patient is now leading a normal life, is married and is teaching He has 90° of neck rotation to the right and to the left and flexion such that he touches his chin to his chest and extension of 20°

DISCUSSION

The anterior approach to the mid and lower cervical spine, popularized by Southwick & Robinson (1955 1957) and further described by Bailey & Badgley (1960) because of the limitations incurred by the superior



Figure 6 Lateral X-ray demonstrating the fusion mass between C-2 and C-3

thyroid artery and adjacent superior laryngeal nerve was inapplicable here, necessitating an extensive search of the surgical literature to provide an answer to the problem in this case The neurosurgical literature in the report of Stevenson et al (1966) and the approach of MacNab (1967) did indicate the feasibility of dissection of the pharyngeal mucosa as far rostrally as the clivus and the vomer We felt that the intrapharyngeal approach, because of a high infection rate reported (Fang 1962), was undesirable in this case Our approach is different from that of Foille & Delmas (1921, 1940) and that of DeAndrade & MacNab (1967) in that it is anterior, thus avoiding the problems encountered in dealing with the extensive number of vital structures traversing the neck laterally

SUMMARY

This approach to the anterior aspect of the first, second and third cervical vertebrae, though a formidable undertaking, obviates certain disadvantages heretofore present In some cases it obviates the necessity of occipital cervical fusion Anterior structures can be readily fused in the presence of damaged posterior neural arch structures, or

other lesions precluding a posterior approach Rotatory motion of the atlas and occiput can be preserved as was demonstrated in this case The time necessary for fusion was reduced to approximately six weeks Vital structures are by and large avoided The objection to the intrapharyngeal approach is hereby overcome

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A COMPARISON BETWEEN CONSERVATIVE AND OPERATIVE TREATMENT OF ACUTE ACROMIOCLAVICULAR DISLOCATION

M ROSENORN & E BRIX PEDERSEN

Accepted 15 v 73

The extensive literature on acute dislocation of the acromioclavicular joint has not so far resulted in a unanimous attitude toward the treatment of this trauma Urist (1959) compiled a list of approximately 50 different methods of bandaging and 30 different operative procedures, each having its enthusiastic supporters However, no direct comparisons appear to have been made between two or more of these methods of treatment In Department T at the Copenhagen County Hospital Gentofte we have, therefore, for a period of 18 months, treated all acute *acromioclavicular dislocations operatively applying the highly recommended* Bosworth Fixation (Bosworth 1941) in a modified form (Kennedy & Cameron 1954, Weitzmann 1967, Reideberger et al 1970) The results of this treatment are compared with those of conservative treatment in another patient material

Knowledge of the normal anatomy of the acromioclavicular joint and the clinical symptoms of dislocation of this joint is taken for granted The final diagnosis is established by radiological examination of the dislocated as well as the uninjured shoulder, exposures being taken without traction as well as with 10 kilograms traction to unsupported arms (Meyers 1968, Moseley 1959) Dislocation of the joint is present when the traction exposure shows the lateral end of the clavicle to be displaced at least one width of the bone above the acromion In rare cases dislocation of the joint involves a distal displacement of the clavicle, its lateral end then appearing below the acromion no such case occurs in our material Subluxation is defined radiologically as an increase in the diastasis between the articular surfaces of the injured joint as compared with the uninjured if, on the application of

traction, the diastasis is seen to increase further without a complete lack of contact between the articular surfaces ensuing

METHOD

A total of 24 patients in whom the diagnosis acute acromioclavicular dislocation had been established previously, have been followed up by the authors

The investigations included radiological and physical *examinations* as well as anamnestic information concerning the period of illness the working conditions and the subjective symptoms.

The patients treated conservatively were followed up at 26 to 124 months mean 84 months after the occurrence of the injury while the patients treated operatively were followed up at 6 to 19 months mean 12.25 months after the injury

MATERIAL

The material comprises two groups of patients

One is made up of those patients who during the *period* 1st January 1961 to 1st January 1971 were admitted to the Copenhagen County Hospital Gentofte *with* acute acromioclavicular dislocation primarily *excluding all* patients with additional fractures of the clavicle or the scapula Twenty three patients were included in this group 7 of whom were excluded as not *fulfilling the criteria* laid down as well as 3 who could *not be traced* This *left* 13 patients 1 woman and 12 *men*, from 24 to 73 years old mean 41.5 *years 3 patients* being older than 50 years) all having received conservative treatment Seven of these patients had had bandages applied for 2 to 4 weeks either according to *the method* of Watson Jones or Madsen's figure-of eight bandage two patients had received *physiotherapy* only for 2 to 4 weeks and 4 patients had not *received any* kind of treatment

The second group is made up of the patients who during the *period* 1st November 1970 to 1st February 1972 were admitted *to the* Copenhagen County Hospital at the Department T with the same diagnosis. Eleven patients were included in this group with ages ranging from 18 to 61 *years* (mean 37 years 3 patients being older than 50 years) There were 3 women and 8 *men* These patients were all operated upon at the latest on the fifth day after the injury The surgical procedure consisted of open *reposition of* the acromioclavicular *joint* with removal of any interposed tissue followed by fixation of the *clavicle* to the coracoid process of the scapula by means of an AO screw Postoperatively *the shoulder* was supported by mitella for 2 to 4 weeks The screw was *removed* on an average 10 weeks later

In both groups highly different *occupations* were *represented* and both groups included patients doing heavy physical work involving the lifting of heavy goods and long hours of work with the arms extended above the shoulders

RESULTS

In the investigation we have distinguished between the functional and the radiological results which appear in Tables 1 and 2

Table 1. A comparison between the functional results of operative and conservative treatment of acute acromioclavicular dislocation

	Good	Fair	Poor	Total
operative treatment	5	4	2	11
conservative treatment	7	5*	1	13

* In one patient the symptoms were localized in the glenohumeral joint rather than the acromioclavicular joint. This patient suffered from degenerative arthritis in several of the other joints.

For the functional results we have used the terms good, fair, and poor defined in the following manner:

Good. No pain, or only rare, short-lasting attacks of pain in connection with certain movements, normal mobility, normal strength, possibly slight cosmetic complaints.

Fair. Pains in connection with certain movements, and/or slight impediment of movement, and/or slightly reduced strength in certain muscular groups, possibly cosmetic complaints. However, none of these complaints were sufficiently serious to necessitate a change in occupation.

Poor. Pains daily, and/or distinctly impeded mobility, and/or distinctly reduced strength. Complaints so serious as to necessitate change in occupation.

The major complaint in connection with the poor functional results in patients treated operatively as well as in those treated conservatively was pain. Objectively all the patients showed normal strength of the entire upper extremity on exposure to a heavy load for a short time, but few claimed a more rapid tiredness of the arm in question during heavy work of long duration. The reduction in mobility was likewise moderate, frequently involving only specific movements and being within 5 to

Table 2. A comparison between the radiological results following operations and conservative treatment of acute acromioclavicular dislocation

	Reduced dislocation	Persisting subluxation	Persisting dislocation	Total
operative treatment	3	5	3	11
conservative treatment*	3	3	5	11

* Two of these patients were not examined radiologically

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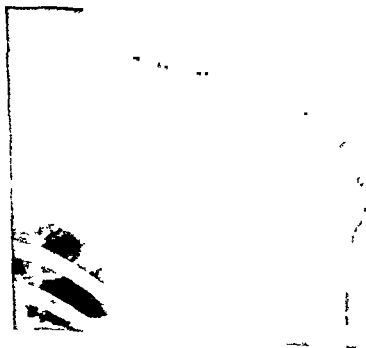


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Figure 2 The radiological results of one case of acute acromioclavicular dislocation treated [illegible]

[illegible] taken with 10 kg traction to each arm

2) persisting subluxation, and 3) persisting dislocation Any sign of calcification or arthrosis was also noted

Radiologically we received the impression—when comparing the primary exposures with those of the present study—that in the majority of the patients operated the dislocation was completely reduced postoperatively, while this occurred in only few conservatively treated



Figure 1 The radiological results of one case of acute acromioclavicular dislocation treated operatively by a modified Bosworth method
A The acute phase of the acromioclavicular dislocation
B The postoperative result
C The follow up result 9 months after removal of the coracoclavicular screw 12 months after the trauma
All pictures are taken with 10 kg traction to each arm

15° In only 2 patients the movements were reduced by 30 to 35° on flexion or abduction In one patient the result was deemed poor, mainly due to persisting paraesthesies, impeded control of movement, and a sensation of reduced strength corresponding to the 3 ulnar fingers of the hand in question, these symptoms arose in connection with the operation Another patient had suffered from similar symptoms during the first 2 postoperative weeks, but these symptoms had later dis appeared completely Apart from these complaints no complications in connection with the operations were registered

Among the 12 patients in whom the results were described as good 6 held jobs entailing heavy physical work—2 of these patients had been treated operatively, 4 conservatively

The radiological results are described as 1) Reduced dislocation,

Table 4 A comparison between the length of the period of illness in patients treated operatively and conservatively respectively for acute acromioclavicular dislocation

	Operatively treated	Conservatively treated
No of days treated in hospital or by GP	9 to 18 days mean 11 days	3 to 9 days mean 5½ days
No of weeks unfit for work	5 to 14 weeks mean 9 weeks	2 to 13 weeks mean 6 weeks
Total number of weeks between injury and present state	5 to 23 weeks mean 12½ weeks	3 to 25 weeks mean 10 weeks

rehabilitation of the joint This was of special importance to patients having a physically heavy job

DISCUSSION AND CONCLUSION

The most enthusiastic supporters of operative treatment, (according to Bosworth s method) for acute acromioclavicular dislocation are Kennedy & Cameron (1954), who prefer a rigid fixation of the clavicle to the scapula thus immobilizing the acromioclavicular joint They claim that the total mobility of the shoulder is maintained because rehabilitation makes possible a synchronic function of the two bones The experience gained from our material of operated patients shows the opposite result as almost all patients despite physiotherapy, suffered from a severely reduced mobility of the injured shoulder during the period in which the clavicle was fixed by means of a screw Other authors (Bosworth 1941 Weitzmann 1967 Riedelberger et al 1971) recommend the method used by us as being the only durable form of internal fixation as cerclage sutures and Kirschner wires are often seen to break silk sutures to snap and ligament plastics possibly with fascial transplants to stretch if the operation is not supplemented with external bandaging (Moseley 1959 Stewart 1963) All supporters of operative treatment of this injury hold the anatomical result to be most satisfactory after operation and maintain that a certain instability of the shoulder almost always persists following conservative treatment (Neviaser 1952 Meyers 1968 as well as the aforementioned authors) Such shortcomings of the conservative treatment are not at all evident in our material Neither subjectively nor objectively did the previous dislocation have any cosmetic sequelae except in the group operated upon in which one woman was dissatisfied with the scar As

patients during the period in which they wore bandages At the time of the follow-up the situation had changed In the operated patients the clavicle was often found to be displaced proximally after the removal of the osteosynthetic material, while at the same time pronounced calcifications had developed around the joint, especially corresponding to the coracoclavicular ligament (Figure 1 A, B, C) In the patients treated conservatively the lateral end of the clavicle had gradually changed and bent downwards, while at the same time the direction of the articular surfaces had changed, the surfaces formerly vertical now slanting, those formerly slanting now almost horizontal, in this manner the extent of the dislocation had decreased and in some cases been reduced completely In this group calcifications were considerably less pronounced (Figure 2 A, B)

In contradistinction to some authors (Weitzmann 1967) we have not found complete correspondence between the functional and the radiological results as is apparent from Table 3 Thus we found 2 cases showing a good functional result despite persisting dislocation, and one case in which the results were poor although the persisting subluxation was very slight The calcifications mentioned did not appear to have any relationship to the functional result, severe calcifications occurring in 2 patients in whom the result was good

Apart from the radiological and the clinical results, the length of the period in which the patients were incapacitated for work was registered for all patients (Table 4) The fact that the length of this period was 1½ times longer for the operated patients than for those treated conservatively was due mainly to the considerably reduced mobility during the period in which the clavicle was fixed to the coracoid process Only after the removal of the screw was it possible to commence an effective

Table 3 A comparison between the functional and the radiological results after acute acromioclavicular dislocation

Functional results	Radiological results			Total
	Reduced dislocation	Persisting subluxation	Persisting dislocation	
good	5	4	2	11
fair	1	3	4	8
poor	0	1	2	3
	6	8	8	22*

* The two patients who were not examined radiologically are excluded

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far as instability of the shoulder is concerned no such condition could be demonstrated objectively, and 7 out of 9 conservatively treated patients doing physically heavy work found the strength in the previously injured shoulder absolutely comparable to that of the other shoulder. The satisfactory results of conservative treatment corroborate the findings of Urist (1946, 1959).

No arthrosis or other late complications from the earlier injury were found in the patients treated conservatively, despite the long observation period. The period of observation for the patients treated operatively was considerably shorter but there are no grounds for assuming that a longer observation period would have shown better results for this group, as all the patients had reached *status quo* several months before the time of this investigation.

The conclusion of our study is that conservative treatment of acute acromioclavicular dislocation irrespective of the method of treatment does not afford less satisfactory functional results than those afforded by operation a.m. Bosworth. Conservative treatment also results in a smaller number of days lost through illness, fewer visits to the general practitioner, fewer days spent in hospital, and the patients are spared the inconvenience of two operations under general anaesthesia. Which of the many conservative methods of treatment should be preferred is not quite clear, but the relatively light and short-lasting bandaging used in this study seems quite sufficient, a fact which has already been demonstrated in previous publications (Stadil 1967).

SUMMARY

The authors have carried out a follow-up of 24 patients with a previous *acute acromioclavicular* dislocation. Thirteen of these patients had received different kinds of conservative treatment. Eleven had been treated operatively with fixation a.m. Bosworth. No significant difference between the functional and the radiological results of the two groups could be demonstrated, but the restitution was more rapid following conservative treatment which is therefore recommended. At the same time it was found that no definite relationship between the functional and the radiological late results could be demonstrated.

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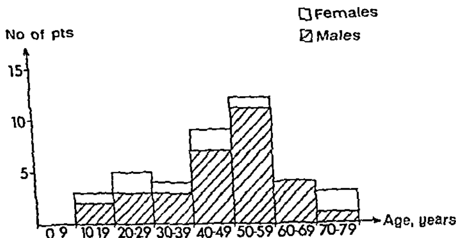


Figure 2 Age distribution and sex ratio of 40 patients with Type III scapular fracture

treated conservatively for scapular fractures of Type III, either comminuted or severely displaced

MATERIAL

The material is from the Odense Hospital where 660 patients with scapular fracture were treated during the 15 year period 1956–1970 A review of all the X ray films disclosed that 40 patients had had comminuted as well as displaced Type III fractures These patients were invited to attend a clinical and radiographic follow up examination The age distribution and sex ratio are shown in Figure 2 Nine were females and 31 males

Table 1 Nature of accident causing scapular fracture in 40 patients

Nature of accident	No of patients	
Road		34
pedestrian	9	
car	10	
motor-cycle	4	
moped	6	
bicycle	3	
unknown	2	
Fall		4
Blow		1
Unknown		1

Thirty one patients had other fractures 4 had injury to the brachial plexus necessitating amputation of the forearm in 2 and one had injury to the axillary

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COMMINUTED AND SEVERELY DISPLACED FRACTURES OF THE SCAPULA

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Accepted 3 v 73

Fractures of the scapula may be divided anatomically, as shown in Figure 1, into three types according to DeCoulx et al (1956) I Fractures of the body II Fractures of the apophysis III Fractures through the superior lateral angle

Type III is generally considered most difficult to deal with

Owing to the anatomical position and muscular protection of the scapula (Harmon & Bauer 1943 Heatly et al 1946 McCally & Kelly 1940, Rowe 1963) considerable force (Findlay 1937, Rose 1963) and as a rule direct trauma are required to give rise to a fracture Consequently patients with scapular fractures often have multiple competitive injuries which take priority over the scapular fracture In planning the primary treatment, the scapular fracture has to be assessed with a view to possible reduction and fixation On the basis of the literature it is difficult to arrive at any therapeutic conclusion We therefore felt it was of interest to conduct a follow up on patients

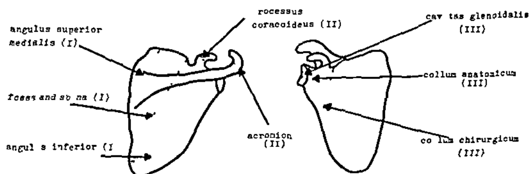


Figure 1 Types of fracture on the two aspects of the scapula
(I fractures of the body II fractures of the apophysis III fractures through the superior lateral angle)

osteoarthritis All the fractures had united, clinically and radiologically

Nineteen patients were symptom free, 9 had pain, 4 of them also at rest Four patients had been obliged to change their occupation, 2 because of the scapular fracture and 2 because of injury to the brachial plexus

Table 4 Radiographic findings in the 28 patients examined at follow-up

	No of patients
Deformity	
mild	5
moderate	11
severe	12
Osteoarthritis	
none	10
mild	17
severe	1

Half the patients had visible deformity, but this deformity was severe in only one case In 10 patients grating was elicited on movements in the shoulder on the affected side

The circumference of the upper arm was reduced by more than 2 cm in 2 patients and that of the forearm in one patient, but reduced strength in the shoulder or upper-arm muscles could not be demonstrated clinically in any case One patient had a loss of sensibility after injury to the brachial plexus All the others had normal sensibility on the arm All the patients were able to carry their hand to the nape of the neck and to the loin Elevation forward-upward with free scapula was restricted in only 2 patients (20°–45°) Elevation outward-upward with free scapula was restricted by 10°–45° in 6 patients, average 30° The remaining patients had normal mobility of the shoulder with free scapula Table 5 presents the restriction of movement in the affected shoulder

Table 5 Restricted mobility in the shoulder joint with fixed scapula in 28 patients

Restriction of mobility	No of patients
elevation	
forward upward (10°–45°)	10
outward upward (10°–40°)	13
rotation	
internal	0
external (10°–20°)	2

artery and underwent amputation at the shoulder The nature of the trauma is apparent from Table 1 The great majority were road accidents

The fracture was due in 23 cases to a direct blow, in one case to indirect trauma whereas in 16 cases the mechanism of the trauma was not stated

Table 2 Site of fracture

Site	No of patients
anatomical neck	2
surgical neck	31
surgical neck + glenoid cavity	7

Table 3 Degree of displacement measured in mm on the X ray films

Displacement in mm	No of patients
<5	2
5 – 9	8
10 – 19	10
>20	20

Table 2 gives the site of the fracture There was no difference between sides, 22 being right sided and 18 left-sided No patient had a fracture exclusively of the glenoid cavity Table 3 gives the degree of displacement Four patients were treated as outpatients and 36 were admitted Six patients were treated in extension with a hanging plaster cast, whereas 18 had no immobilizing treatment

All were instructed in static contractions and as soon as the immobilization was discontinued in active movements Local anaesthetics were not administered in any case and brisement force was not used

RESULTS

Of the 40 patients, 4 died after the accident, 2 had died of other causes before the time of follow-up, 1 was living abroad, 2 refused to be examined, and 2 could not be traced through the national registry One patient had had an amputation at the shoulder and was not examined Of the patients seen at follow-up 5 were females and 23 males The youngest patient had been 13 and the oldest 72, mean age 43 7 years, at the time of the accident The longest follow-up period was 8 years, the shortest 2 months, mean 8 years 11 months Only one patient had a follow up period of less than 2 years

Table 4 gives the X ray findings with respect to deformity and osteo arthritic changes Patients with radiological evidence of osteoarthritis were divided into two groups by severity mild, with slight sclerosing of the joint surfaces and formation of osteophytes, and severe with marked sclerosing and subchondral cysts Only one patient had severe

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rotation	
internal	0
external (10°–[illegible]0°)	2

DISCUSSION

Fracture of the scapula is relatively uncommon (Harmon & Bauer 1943, Heatly et al 1946, McCally & Kelly 1940, Rowe 1963), and displaced scapular fractures quite particularly rare Among 2374 fractures, Newell (1927) found about one per cent to have affected the scapula, and thereof about 10 per cent were displaced or comminuted The explanation is presumably the favourable position and mobility of the scapula Of our 660 patients with scapular fracture, only 40, or 6 per cent, had displaced or comminuted fractures of Type III The displacement may be considerable Thirty of our 40 patients had displacement exceeding 1 cm The trauma which they had sustained was often very severe, especially in the road accidents The majority of patients have associated injuries This applied to 36 of our 40 patients Most patients belong to the occupationally most active age group (Rowe 1963), and this was confirmed by our series

The literature on scapular fractures is rather meagre, but several authors feel that operative treatment should be considered in severely displaced fractures of the glenoid cavity (Fischer 1939, Harmon & Bauer 1943, Rowe 1963) All the patients of our material had been treated conservatively Most interest is attached to fractures through the glenoid cavity, as these fractures are intraarticular Eight of our patients had fractures through the glenoid cavity, but in all these cases there was also a fracture of the surgical neck Of these patients 5 had died at the time of follow-up, and the remaining 3 were free of pain and had continued in their former occupation However, only one had full mobility, 2 having an outward-upward elevation restricted by 20° 30° with fixed scapula

Reduction of strength could not be demonstrated in any case, and none had restriction of mobility to the extent of inhibiting function, especially not with a free scapula, the mobility of the scapula compensating to some extent for restricted mobility in the humero scapular joint

According to our findings, conservative treatment, even of severely displaced as well as comminuted scapular fractures, appears to afford fully satisfactory results, functionally and occupationally

SUMMARY

At the Odense Hospital 660 patients with scapular fractures were treated during the 15-year period 1956–1970 Of this number 40 had

severely displaced as well as comminuted fractures of Type III according to the classification of Pierre DeCoulx

Most of the patients had sustained violent trauma causing multiple injuries, as a rule in road accidents Thirty-one patients had associated fractures, 4 had injury to the brachial plexus, and one had injury to the axillary artery

All the scapular fractures were treated conservatively Of the 40 patients 28, 5 females and 23 males, were examined at follow up after an average period of 8 years 11 months, 19 patients were symptom free, and only 2 had had to change their occupation because of the scapular fracture

There was no instance of reduced strength, and a slight restriction of mobility was found in only 6 patients

Our investigations show that conservative treatment, even of severely displaced as well as comminuted scapular fractures, affords fully satis factory results

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SUMMARY

At the Odense Hospital 660 patients with scapular fractures were treated during the 15-year period 1956–1970 Of this number 40 had

Figure 1 Classification of the fractures affecting the radial head and neck into type A to F The number of fractures within each type is given (operated cases in brackets)



Type A 8
Fracture line without any displacement

Type B 14
Fracture in which one fragment is displaced less than 1 mm

Type C 25(2)
Fracture in which one fragment is displaced more than 1 mm







Type D 5
Fracture with more than two fragments but as one unit

Type E 8 (7)
Fracture with more than two fragments which are apart

Type F 7
Fracture of the neck only

of full extension and with medium rotation of the forearm The plaster cast was worn for varying periods as may be seen from Table 1 However, 24 of the 58 conservatively treated cases were not fitted with a plaster cast

Table 1 Duration of plaster immobilisation of the various non-operated cases

Type of fracture	A	B	C	D	F	F	Total
Without plaster	2	7	9	2	0	4	24
Plaster 1 2 weeks	4	2	6	0	0	0	12
Plaster 2-3 weeks	0	3	6	2	0	1	12
Plaster 3-4 weeks	2	1	0	1	1	1	6
Plaster more than 4 weeks	0	1	2	0	0	1	4
Total	8	14	23	5	1	7	58

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FRACTURE OF THE HEAD AND NECK OF THE RADIUS

Follow-up on 61 Patients

JENS O POULSEN & KNUD TOPHOJ

Accepted 3 x 73

Opinions are divided as to the methods of treating fractures affecting the head and neck of the radius Meekison (1945), stating that the head is to be excised in all fractures, represents the operative extreme. The extreme conservative treatment is represented by Charnley (1963) who advised excision of the radial head only if rotation of the forearm was restricted after 2 weeks' training In between these extremes, most therapeutic patterns are grouped, using conservative treatment of the less displaced and operation of the more displaced fractures

By submitting the present material, we want to demonstrate that the vast majority of fractures in the head and neck of the radius may be treated conservatively with good results

MATERIAL

The material comprises all fractures of the head and neck of the radius treated in the Orthopaedic-Surgical Hospital Soro Denmark during the period January 1958 to November 1968

Patients with associated fractures or dislocation of the elbow were excluded So were fractures in children i e patients in whom open epiphyseal lines were seen on the X ray films Thereafter, the material comprises 48 females and 17 males, two had bilateral fracture, making a total of 67 fractures 25 patients were treated on an out patient basis and 40 were admitted

Thirteen patients were in the age range 15–30 36 were 31–65 and 16 were over 65 years of age

There are different ways of classifying fractures of the radial head and neck (Adler & Shaftan 1963 Bakalim 1970 Johansson 1962 Carstam 1951) As we could not naturally classify the fractures according to the named systems we designed the system shown in Figure 1

TREATMENT

Non-operative treatment consisted in fitting a dorsal plaster cast from the knuckles to high on the upper arm, with the elbow about 80° short

Table 3 Data for 9 operated fractures

Type of fract	Type of operation	Plaster cast	Restriction of movement at follow up				Pain	X ray appearances	Total result
			ext	flex	sup	pron			
F	Removal of head	None	5°	0°	0°	0°	Negligible	Head irregular A fragment 6 × 8 mm has not united	Good
I	Excision of head	None	2°	0°	0°	0°	Slight when the weather is changing	Excision line smooth	Good
C	Arthrotomy and reduction No internal fixation	Plaster for 3 weeks	0°	0°	0°	0°	Slight	Fracture united and head of normal outline	Excellent
I	Arthrotomy reduct and fix with catgut sut	Plaster for 2 weeks	0°	0°	60°	20°	None	Head irregular Fracture united	Poor
F	Excision of head	Plaster for 3 weeks	0°	0°	0°	0°	Negligible	Fracture united	Excellent
I	Removal of displaced fragment	Plaster for 3 weeks	0°	0°	20°	0°	Slight on heavy strain	Head irregular A fragment, 5 × 5 mm not united	Poor
C	Removal of displaced fragment	None	3°	0°	0°	0°	Slight on heavy strain	Head irregular	Good
F	Reduction without arthrotomy	Plaster for 3 weeks	5°	0°	60°	10°	None	Head irregular Fracture united	Poor
F	Excision of head	None	0°	0°	15°	0°	None	Excision line smooth	Poor

Table 2 Relationship between length of training period for elbows fixed in plaster and non-immobilized elbows

	non immobilized	immobilized in plaster
Training 0–1 week	3	1
Training 1–2 weeks	3	11
Training 2–3 weeks	0	7
Training more than 3 weeks	7	15

Training in non-immobilized cases was started as soon as the pain had almost subsided, as a rule in 2 or 3 days In the patients with plaster casts training was started as soon as the cast had been removed The training was under the guidance of a physiotherapist, whether it was on an in-patient or out-patient basis

The training period ranged from less than one week to more than three weeks (Table 2) Data are available concerning the training period for 48 patients During the training period 7 patients had been provided with an abduction splint to counteract swelling of the elbow

Nine fractures were treated by operation Their data are given in Table 3 All the operations were performed within 10 days of the fracture The training period for operated patients who were fitted with a plaster cast ranged from three weeks to six months

FOLLOW UP

The follow-up was conducted in the autumn of 1969 The mean follow-up period was 5 2 years Four patients were not seen as one had died and three refused to attend

Sixty-one patients with 63 fractures were examined at follow-up, 54 had been treated conservatively and 9 by operation At follow-up all patients were examined clinically and 58 patients, with 59 fractures, were also examined by radiography On the basis of the patient's statements and the clinical examination the result was recorded as excellent, good, or poor

Excellent No subjective complaints or negligible symptoms, i e occasionally mild pain on unusually severe strain or changes in the weather Unchanged working ability No limitation of motion

Good Occasionally mild pain on unusual strain or changes in the

poor group Three operated cases exhibited similar avulsions—one of the good and two of the poor results group Signs of osteoarthritis were not observed in any case None of the conservatively treated patients had upward displacement of the radius which was seen in two cases treated by excision of the radial head None of these patients had wrist complaints

DISCUSSION

The mechanism of trauma in fracture of the head and neck of the radius has not been consistently elucidated (Johansson 1962) If the fracture is caused by direct trauma to the elbow, it might be interpreted as an isolated injury If, on the other hand, it is the result of an indirect trauma represented by a force acting upon the entire elbow, the fracture is not likely to be an isolated injury

According to Radin & Riseborough (1966) direct and indirect traumas are equally common causes of these fractures

Dickson (1949), Johansson (1962), Watson Jones (1955), and Keon Cohen (1966) believe that the fracture is caused by a blow which is transmitted, via the hand and forearm, to the elbow Palmer (1961) has compared the mechanism with that in the knee, when the lateral femoral condyle collides with the lateral tibial condyle, causing a fracture of the latter

Broadly speaking, it is widely agreed to interpret the fractures of the head and neck of the radius as a link in an extensive damage to the elbow with injury to the capsule and collateral ligaments We share this view We feel that our classification from type A to E corresponds fairly well to the severity of the trauma causing the fracture, so that there is a relationship between the type of fracture and the total damage to the elbow

Carstam (1951) interpreted small avulsions of bone at the attachment of the capsule as being equivalent to ruptures of the capsule or ligaments In nearly all his cases he found small avulsions of bone on the follow up radiographs In our material we found avulsions of bone in 8 cases 2 of type B 3 of type C, and 3 of type E Indeed, the tendency is for the avulsions to be most common in the most severe fractures

Care should be taken when comparing different fractures, as there is a risk that those injuries in the elbow which are not known are not comparable If there is to be a chance of having comparable injuries, we feel that at least each type of fracture should be compared separately

weather and unchanged working ability Limitation of motion of up to 10° in one direction

Poor Daily pain reduced working ability and/or limitation of motion exceeding 10° in one or more directions

Table 4 gives the results for the 54 conservatively treated cases assessed by these criteria Some of the results warrant further comment

One type B fracture was assessed as poor because of a 40° extension defect and a restless feeling after prolonged strain At follow up there was free rotation and radiography gave no explanation of the extension defect This patient had been trained for 8 months

Table 4 Results in 54 non operated fractures at follow-up

Type of fracture	A	B	C	D	E	F	Total
Excellent	7	11	19	4	1	6	48
Good	0	2	0	1	0	0	3
Poor	0	1	2	0	0	0	3
Total	7	14	21	5	1	6	54

Two type C fractures were assigned to the poor group one because of a 20° extension defect no other complaints The other patient had free mobility but complained of daily pain X rays revealed avulsions of bone where the capsule attached to the humerus

Summing up it may be said that none of the unoperated conservatively treated patients had deficient rotation in the forearm and only one had major limitation of motion *viz* a 40° extension defect The results for the 9 operated patients are given in Table 3

In the radiographic follow up we looked for a possible increase in the width of the radial head union of the fracture signs of osteoarthritis avulsions of bone and relative lengthening of the ulna at the wrist

An increase in the width of the radial head exceeding 1 mm was found in 9 cases—5 with excellent 3 with good and one with poor results

In three cases union had failed there being a diastasis between a displaced fragment and the main fragment These cases were in the group of excellent results

Five non operated cases showed small avulsions of bone medially and/or laterally at the attachment of the capsule to the humerus Three of these cases were in the excellent one in the good and one in the

Adler & Shaftan use conservative treatment without regard to the size of the fragment or its displacement

The present material included 24 fractures of this type, 22 had been treated conservatively, with a satisfactory result in 20 and a poor result in 2 One of the latter had normal mobility, but pain The X-ray film showed avulsions of bone This patient had been in plaster for 2–3 weeks The other one had an extension defect and had not been in a plaster cast

Two had been treated by operation, one by reduction and fixation, with an excellent result In the other case the fragment was excised The result was good with slight extension defect and mild pain In this case there were avulsions of bone, indicating a more extensive injury

Types D and E

Radin & Riseborough (1966), Bakalim (1970), Keon Cohen (1966), and Watson Jones (1955) recommend excision of the radial head in these types of fracture Adler & Shaftan (1963) and Castberg & Thing (1953) found acceptable results without operation, if the fragments were not separated Charnley (1963) advised against primary operation, but if a rotation defect persisted after training, he recommended excision of the head

Bakalim (1970) found that 19 out of 59 fractures were spontaneously reduced when treated by early mobilization

The operative procedure may be excision of the head or removal of loose fragments Reduction or any other form of internal fixation is not recommended in these types of fracture

Carstam (1951) has recommended that to some extent the operation be restricted to removal of loose fragments viz when a material part of the head is intact

There is disagreement about the time of operation, if any Watson Jones (1955) Keon-Cohen (1966), and Carstam (1951) recommend operation in the course of the very first days saying that during this period ectopic ossification is least common

Adler & Shaftan (1963) and Arner et al (1957), on the other hand, found no relationship between this complications and the time of operation Charnley (1963) recommended waiting at least 2 weeks, stating that thereby he has never seen ectopic ossification

Our 5 cases of Type D were treated conservatively, 4 with an excellent result and one with a good result, having a slight extension defect and rare pain

Type A

Meekison (1945) advised excision of the head in this type of fracture, whereas most other authors recommend a conservative treatment pattern with early active training, possibly after fixation in plaster for a time until the patient is free of pain (Adler & Shaftan 1963, Arner et al 1957, Radin & Riseborough 1966, Castberg & Thing 1953) Bakalim (1970) feared that too early mobilization involved a risk of secondary displacement of the fragment

Our follow-up study included 6 patients with this type of fracture, all of whom had been satisfactorily treated conservatively

Type B

Opinions are more divided concerning the management of this type of fracture Charnley (1963) advised immobilization for 2 or 3 days, followed by active exercises Bakalim (1970) immobilizes for one week The same has been recommended by Castberg & Thing (1953), Arner et al (1957), Adler & Shaftan (1963) Radin & Riseborough (1966) used longer-lasting immobilization because of the risk of displacement, and Dickson (1949) also advocated more prolonged fixation Keon-Cohen (1966) excised the head or fragment at the end of a few days

Our material comprised 14 cases of this type, all treated conservatively, 11 had an excellent, 2 a good, and 1 a poor result The cause of the one unsatisfactory result was an extension defect and pain As stated by Charnley (1963), it seems unlikely that an extension defect can be a consequence of the fracture itself On the other hand, it may reasonably be ascribed to a capsular injury One of the patients with avulsions of bone had a moderate extension defect and was grouped as a good result

We suggest a treatment plan for this type of fracture similar to Charnley's (1963) A few days' immobilization and early training The patient who had a poor result had worn a plaster cast for 3 4 weeks One of those with a good result had worn a cast for 1–2 weeks, whereas the other one had not been immobilized

Type C

What has been stated for Type B applies in fact also to Type C However, Radin & Riseborough (1966) feel that this type should be treated by excision of the head, if the fragment makes up more than two-thirds of the head, otherwise they recommend conservative treatment

trauma If this can be done without removal of the fragment, it is preferable, but if the exercises give rise to severe pain, it is recommended to remove the fragments at the end of 4–5 days, so that early training can be instituted

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Of the 8 Type E fractures one did not have an operation, and the result was excellent, 7 underwent operation, and one obtained an excellent result

Type F

This type is often grouped with Type A (Johansson 1962), also with respect to treatment Our 6 cases were treated conservatively, with satisfactory results

Should any capsular and ligamentous injuries be repaired Johansson (1962) combined treatment of the fracture and of the capsule/ligaments in 20 cases Eight obtained free mobility in the elbow, whereas the remainder had a severe extension defect and one had ectopic ossification These results are poorer than those of treating the fracture only and using early mobilization

SUMMARY

Fracture of the head and neck of the radius is interpreted as that part of a more extensive cubital injury which may be demonstrated on an ordinary X-ray film Other associated injuries are damage to the joint capsule and collateral ligaments, and cartilaginous damage on the capitulum of the humerus and the head of the radius

The fractures were classified into groups It was endeavoured to make the grouping correspond to a gradually greater action of force and total damage in the elbow

During the study period 67 fractures were treated, 58 conservatively and 9 by operation The conservative treatment consisted in no fixation or in plaster fixation for up to 4 weeks Thereafter, training by active exercises

Of the 63 fractures examined at follow-up, 54 had been treated conservatively The result was excellent in 48, good in 3, and poor in 3

On the basis of these results and studies of the literature it is concluded that fracture of the head and neck of the radius of types A, B, C, D, and F should be treated conservatively with 2–3 days' immobilization followed by active exercises

For type E no definite treatment plan can be laid down on the basis of the present material Reports in the literature are so heterogeneous that they also cannot support any definite procedure Feeling that early mobilization is of decisive importance, the present authors recommend a plan in which training is instituted a few days after the

trauma If this can be done without removal of the fragment, it is preferable but if the exercises give rise to severe pain, it is recommended to remove the fragments at the end of 4–5 days so that early training can be instituted

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SECONDARY DISPLACEMENT OF REDUCED DISTAL RADIUS FRACTURES

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Accepted 7 v 73

The correct treatment of a distal fracture of the radius is still a subject of divergent views in the literature Correct anatomical healing, however, is generally regarded as desirable This presupposes good reduction, fixation and effective control of possible redislocation, in order to be able to correct it when necessary Apart from a few works, the literature does not offer details about the exact time of secondary displacement of reduced distal radius fractures We consider this time factor is important in order to determine when and how often X-ray examinations should take place In this way we can avoid unnecessary checking of the patients and also reduce the costs of treatment In order to determine the frequency and exact time of secondary displacement after the reduction of the distal fracture of the radius, we examined prospectively one hundred cases with planned frequency and interval of X-ray checks

MATERIAL AND METHODS

All fractures of the distal radius treated at the Department of Surgery I of Sodersjukhuset Stockholm between 1st November 1971 and 29th February 1972 were registered and checked by X ray examinations 5–7 10–15 15 20 and 36–40 days after the incidence of the fracture This relatively large spread was unfortunately unavoidable as the X ray Department serves only emergency cases on Saturdays and Sundays After having excluded cases where primary reduction was not indicated and fractures which were incompletely controlled there remained 100 cases

Of the 100 cases 85 were women and 15 were men 67 of the women and 11 of the men were over 50 years of age At the first evaluation of the degree of displacement consideration was taken of both dorso volar and radio ulnar angulation and of possible dislocation *ad axin* as well In the following presentation however we have preferred to illustrate only the dorso volar angulation in order to obtain better surveyability

Table 1 Material 100 reduced fractures

Age	♂	♀
20		
21 35	2	5
36–50	2	13
51–65	7	44
> 66	4	23
Total	15	85

Table 2 Classification of fractures of the distal radius according to Frykman (1967)

1 Extra articular fractures without fracture of the distal ulna
2 Extra articular fractures accompanied by fracture of the distal ulna
3 Intra articular fractures involving the radio carpal joint but without fracture of the distal ulna
4 Intra articular fractures involving the radio-carpal joint and accompanied by fracture of the distal ulna
5 Intra articular fractures involving the distal radio ulnar joint but without fracture of the distal ulna
6 Intra articular fractures involving the distal radio ulnar joint and accompanied by fracture of the distal ulna
7 Intra articular fractures involving both the radio-carpal and the distal radio ulnar joint but without fracture of the distal ulna
8 Intra articular fractures involving both the radio carpal and the distal radio ulnar joint and accompanied by fracture of the distal ulna

Table 3 Material Types of fractures according to Frykman

Type of fracture	Number
1	8
2	18
3	2
4	4
5	15
6	42
7	3
8	8
Total	100

Types of fracture

We adapted Frykman's (1967) system with eight groups of fractures.

The different types of fractures in the present material are shown in Table 3 which indicates that in more than 40 per cent of the cases both the radio ulnar joint and the styloid process of the ulna were involved at the same time

Immediate closed reduction was performed in all cases most frequently under general anaesthesia The primary immobilization consisted of a dorsal plaster

splint which, in two thirds of the cases, was completed by a circular plaster on the forearm applied 7 or 14 days after the injury

RESULTS

In the following figures we only present secondary dislocations exceeding 10° dorso-volar angulation As an illustration of the dynamics of the secondary dislocation, however, it is interesting to note that in 40 of the 100 cases we found secondary dorso-volar angulation less than 10°

Of 100 cases we found 20 with secondary dislocation measured by a dorso-volar angulation exceeding 10°

Figure 1 illustrates the incidence of fresh redislocations at each check i e *the number of first-discovered redislocations* The incidence is about the same after 5–7 or 10–15 days and there is only one fresh redislocation at the third check

Figure 2 illustrates the cumulative number of redislocations found during the checks The degree of dislocation is compared with the position of the fracture obtained after reduction and the diagrams comprise *both* first-discovered redislocations *and* further redislocations since the previous check This figure shows the importance of repeated

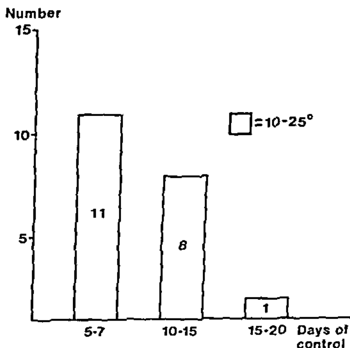


Figure 1 The number of first discovered redislocations

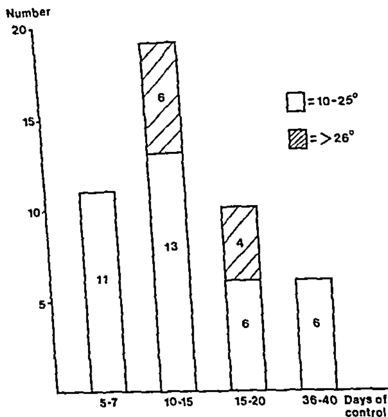


Figure 2 Cumulative number of redislocations

checks and indicates the continuous process of tilting of the distal fragment We find a peak at the second check (10–15 days after the injury)

Figure 3 shows the continuous process of secondary dislocations, comparing the angulation with the position of fracture at the previous check i e the diagrams illustrate the occurrence of redislocations *between* two checks As in Figure 2 we find that the most important period of observation seems to be between the first and second check i e 5 14 days after the reduction of the fracture

We have also examined the relationship between the result of primary reduction and the later secondary dislocation We can not find evidence for lower frequency of secondary dislocations obtained by exact anatomical reduction

The technique of immobilization – dorsal plaster splint or alter-

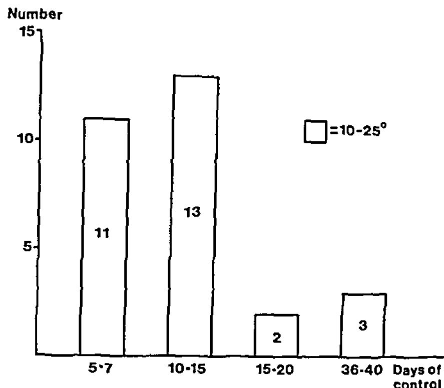


Figure 3 The frequency of the continuous redislocation

natively circular plaster – does not seem to influence the frequency of secondary dislocation

DISCUSSION AND CONCLUSIONS

The importance of the problems connected with fracture of the distal radius has given rise to two theses within the last decade in Sweden (A Lidstrom 1959, G Frykman 1967) Lidstrom (1959) tackles the problem of redislocation but without mentioning when it occurs Madsen (1949)—who included 24 cases with dorso-volar angulation less than 10°—found an approximately equal number of redislocations during the first 3 weeks after the injury Lidstrom (1959) quotes both Cornell and Sirbu & Collof who maintained that the second week and the first 10 days after reduction, respectively, were the critical periods for redislocation We have found that most secondary displacements occur less than 15 days after the reduction of the first fracture Consequently this gives an indication of the time of the first X ray check which could take place 10–14 days after primary reduction The following X-ray checks should be determined individually depending on the

type of fracture and the development of any redislocation with constant awareness of the possibility of late debut of redislocation

We want to mention as an accessory finding of this investigation the occurrence of 6 patients with fracture of the distal radius where primary reduction was not considered as necessary These fractures, however, underwent a continuous displacement which reached an unacceptable angulation in all 6 cases In the literature we could not find any mention of the necessity of X ray checks in fractures with such a low degree of angulation that reduction was not carried out

SUMMARY

In a prospective investigation 100 fractures of the distal radius were the subject of repeated frequent X-ray examinations in order to deter mine the frequency and exact time of secondary displacement Secondary displacement exceeding a dorso-volar angulation of 10° occurred in 20 per cent of the cases Most of the displacements took place less than 15 days after the primary reduction In spite of the relatively limited series the authors consider that a change in the routine of X ray checks would result in more effective and less elaborate treatment of a very large group of patients and at the same time reduce the costs of treatment The first X ray check, therefore, could take place about 2 weeks after primary reduction of the fracture and the frequency and interval of following X ray checks should be determined individually Fractures with a primary displacement where reduction was not regarded as necessary, should be checked in the same way

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PSEUDARTHROSIS IN THE SCAPHOID BONE TREATED BY GRAFTING WITH AUTOGENOUS BONE-PEG

A Follow-up Study

STAFFAN TORNGREN & STURE SANDQVIST

Accepted 4 xi 73

Discussions regarding the best method of operative treatment for pseudarthrosis in the scaphoid bone have continued over many years and different methods have been tried The methods of choice nowadays seem to be transplantation of cancellous bone and chips, introduced by Matti & Russe (Mulder 1968, Dooley 1968) or screw osteosynthesis combined with bone chips (Vorrhoeve 1970) Palmer introduced a method earlier described by Adams & Leonard in 1928 and Murray in 1946 to Sodersjukhuset at the end of the nineteen-forties The method involves drilling of the scaphoid bone from a radial approach and transplantation of an autogenous bone-peg through the pseudarthrosis The bone-peg was usually taken from the tibial crest but in some cases from the ulna or fibula Palmer & Widen published the results in 1955 and the study showed a 100 per cent frequency of union In the following article we give the results of all patients treated with this technique at Sodersjukhuset, Surgical Department I A similar follow-up of 11 patients has recently been published by Agner & Andersen (1970) In that study five showed union but no correlation was found between x-ray proven union and the functional result The present study will give a survey of the frequency of union after the above-described operation and the functional results and secondary osteoarthrosis The patient group which could not be followed up was analysed from the records

MATERIAL

Between 1947 and 1971, 58 patients were operated on for delayed union or non union of scaphoid fractures Six patients had died two were reported missing and a further five persons were unable to take part in the follow up The material consists of 46 cases of pseudarthrosis of the scaphoid bone, eight fractures with delayed union and four recent fractures

50 persons were grafted with an autogenous bone peg and of these, 41 were followed up with clinical and x ray examinations and a further four could be judged as truly united according to the last x ray film in the records, without a new examination

The information (before and after the operation), which we could collect, was limited because the journals usually did not include the out patient department records and these were only kept for five years The x ray pictures for this period have not been kept in the archives We have not been able to compare the degree of arthrosis and the types of fractures before operation with the results of the follow up Three surgeons performed most of the operations by the same method and there is no real difference in the frequency of union between the various surgeons Most of the patients had a plaster fixation according to Bohler and during the last 5–6 years according to Verdan The injuries were approximately equally divided between the right and left sides

METHOD

The follow up study was done in October 1972 and included clinical and x ray examinations Some patients who had moved to another part of Sweden, were contacted and x rays were taken in some of these cases Two persons were examined within two years after operation nine between 2 10 years and 30 after more than 10 years

We recorded the range of movement of the wrist in the four main directions and strength was measured with a dynamometer The mobility was considered normal when the patient himself thought that he had normal mobility The grading in functional groups is showed in Table 1

Table 1 The definition of moderately and severely decreased mobility The mobility is considered normal when the mobility is better than the highest figure in the table

Mobility	Moderately decreased	Severely decreased
Dorsal	30–50°	0–30°
Palmar	40–65°	0–40°
Ulnar	10–25°	0–10°
Radial	5–15°	0– 5°

The follow up x rays performed with conventional techniques gave information of union or non union Pseudarthrosis is established when the x ray films show a fracture with well defined margins relatively smooth surfaces and sclerosis Furthermore the degree of arthrosis in the radiocarpal joint was classified into three groups independently of the clinical judgement The osteoarthrosis has been divided into three stages 1 little or no arthrosis 2 moderate arthrosis and 3 severe

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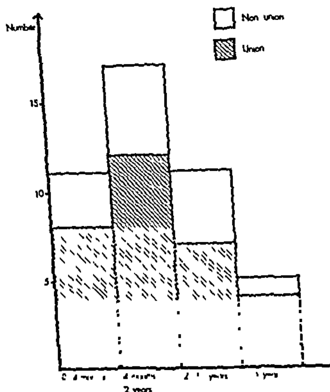


Figure 1 The number of united and non united fractures of the scaphoid bone related to the interval between fracture and operation (One patient has no information about trauma)

an X ray and one was operated on later for arthrodesis of the wrist In both groups there are many patients with decreased mobility of the wrist The difference between the two groups is small and five persons have normal mobility in spite of persisting pseudarthrosis (Table 2)

The frequency of union is probably not related to the interval between fracture and operation (Figure 1) Perhaps there is a preponderance of pseudarthroses in the group with an interval of 2–10 years between fracture and operation However, the age at operation seems to be an important factor for union or non union Under 40 years of age there is a 75 per cent frequency of union and over 40 years of age it is 55 per cent (Figure 2)

There is an interesting group of five persons who in 1955 in the

arthrosis The first group consists of cases without visible alterations and cases where the cartilage has been found to be two mm or more and where only small osteophytes have been seen The second group with moderate arthrosis consists of cases with a cartilage thickness less than two mm where the osteophytes have been moderately developed and where small subchondral sclerosis or cystic rarefications have been seen Severe arthrosis includes complete obliteration of joint space with large osteophytes and with large sclerotic and cystic areas

RESULTS

In 32 of the 45 grafted patients union was obtained but seven of these were not given an x-ray examination at the follow-up study True union was recorded in earlier x-rays in these cases The 32 persons with union could be divided into 25 with established pseudarthrosis of the scaphoid bone, six with delayed union and one with a recent fracture A total of 28 praticipated in the follow-up study Six often experienced pain and other types of troubles but 80 per cent had no discomfort (Table 2) Eleven had little or no arthrosis according to the x-ray, thirteen had moderate arthrosis and one patient had severe arthrosis

Table 2 The distribution of mobility pain and discomfort in the two groups of union and non union

		Union	Non union
Mobility	Normal	10	5
	Moderately decreased	17	7
	Severely decreased	1	1
Strength	Normal	23	8
	Decreased	5	5
Pain and discomfort	No	22	8
	Yes	6	5

Thirteen persons still have pseudarthrosis Of these, eleven had pseudarthrosis, one delayed union and one a recent fracture of the scaphoid bone Five patients had often experienced pain and trouble (including one case of secondary arthrodesis) In this group the frequency of subjective troubles was twice as high but 60 per cent had no symptoms (Table 2) Osteoarthrosis was more pronounced in this group, two had little arthrosis, nine moderate, one did not have

The different forms of osteoarthrosis are shown in Table 3. There is a slight tendency to more developed arthrosis in the non union group together with decreased mobility.

Table 3. The mobility of the wrist in the different groups of osteoarthrosis

Mobility	Arthrosis	None or little	Moderate	Severe
Normal	Union	5	2	0
	Non union	0	4	0
Moderately decreased	Union	6	10	1
	Non union	2	5	0
Severely decreased	Union	0	1	0
	Non union	0	0	0

CONCLUSIONS

The operative treatment of pseudarthrosis of the scaphoid bone involves great difficulties. Earlier works on the subject have shown the limitations of this method in achieving union and good results in patients with this condition. This investigation confirms that. It is therefore important not to neglect the primary management of wrist trauma as regards diagnosis, fixation and control in order to avoid pseudarthrosis. Wrist sprains with primarily negative x-ray films should be rechecked after about a two-week interval with a new x-ray examination. Fractures of the scaphoid bone should be fixed with plaster according to Verdan and the patient checked until x-rays show union.

SUMMARY

Between 1947 and 1971 at the Surgical Department I, Sodersjukhuset, 58 patients were operated on with some type of procedure for the scaphoid bone. 50 of these were grafted with an autogenous bone-peg through a radial approach in the fossa Tabatiere. Of these 45 were examined for union and 41 took part in a follow up investigation. 32 were found to be united but 13 still have a pseudarthrosis. We have found that the most important factor for union is the age of the patient, the younger the patient the higher the frequency of union. In the two groups there is rather strong tendency to osteoarthrosis in the radiocarpal joint

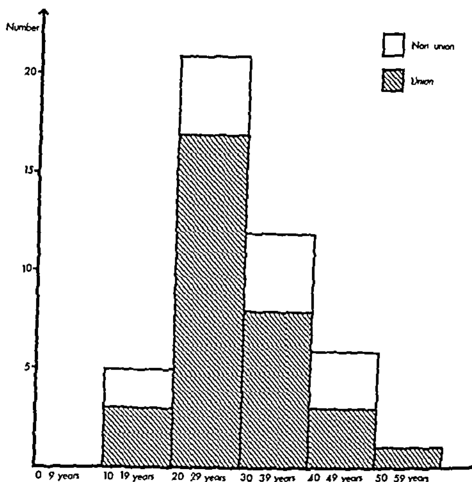


Figure 2 The number of united and non united fractures of the scaphoid bone related to the age of the patient at operation

earlier follow-up investigation were considered united and these results were recorded At this follow up they show persisting non-union The patients had had increasing signs of union and no pain after 4–12 months They had an average age at operation of 33 years and an interval between fracture and operation of two years (41 days 4 years) They were examined and now had slight trouble one had slight arthrosis and the rest moderate arthrosis A long range follow up investigation seems necessary in order to obtain the true frequency of union

All patients in the follow up study were asked about decreased sensitivity and numbness in the thumb in order to diagnose injuries of one of the small cutaneous branches from the radial nerve In six cases we found a total or partial nerve damage

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CUP ARTHROPLASTY IN PATIENTS WITH RHEUMATOID ARTHRITIS

HÅKAN BRATTSTRÖM, CARL-AXEL CEDELL, ÅSA HAGSTAM & HELEN LINDÉN

Accepted 13 vi 73

Total hip replacements have come to play a more and more dominating part in hip surgery There are wider indications and the method is used in progressively lower age groups These trends were evident at the SICOT meeting in 1972 It is also clear from series with longer observation periods that difficult problems may arise in time, loosening of the prosthesis, infections and wear out being the most common Above all it is the infected cases which give difficulties and an insufficient hip is in some cases the end result as the prosthesis has to be removed and the neck of the femur has already been resected Warning voices were raised (e g Coventry 1972), and not least Charnley in his speach on "the second line of defence" has cautioned against an uncritical use of total hip replacement in the lower age groups Cup arthroplasty has been proposed as an alternative for younger age groups i e patients under 45 50 years If a cup arthroplasty becomes infected or for some reason is unsuccessful the patients have other alternatives (fibrous or osseous anchylosis, total arthroplasty, resection angulation or eventually a new cup arthroplasty)

In cases of rheumatoid arthritis an operation is often relevant in young people and those in their early middle age Arthritis in the hip joint may be extremely painful and through a flexion and/or adduction contracture cause a secondary valgus strain and flexion contracture in the knee and sometimes fixed plantar flexion of the ankle The pains and the restriction of movement cause great difficulties in [illegible]

[illegible] years of age a total arthroplasty or first of all a cup arthroplasty?

and moderately decreased mobility In the pseudarthrosis group however, there are some patients with little discomfort and essentially normal mobility and in the united group some patients with severe arthrosis and discomfort This investigation confirms the limitations of this method in achieving union in patients with pseudarthrosis of the scaphoid bone

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osteoporosis of the leg There were no diagnosed cases of thrombosis, lung embolism or heart complications In three women with four hip plasties supplementary *dorsal synovectomy* or removal of osteophytes was performed one to two years after the plasties Aufranc (1962) and Johnston & Larsson (1969) report that revision was required in one third of the rheumatic cases, i e rather more frequently than in other patients

Table 1 Cup arthroplasty in rheumatic diseases 1966–1970

	1966	1967	1968	1969	1970	
No of hips	1	8	16	9	2	
No of patients	30 (22 female, 8 male)					
No of hips	36 (27 female 9 male), 18 dx, 18 sin					
Mean age at operation	44 (15 71) years					
Age period	15–24	25–34	35–44	45–54	55–64	65→
No of hips	6	7	6	8	6	3
Type of arthritis	Juvenile		Adult		Bechterew	
No of patients/hips	5/6		25/27		2/3	
Mean duration of disease at operation years	6(3–8)		13(2–45)		5(5–6)	
Mean duration of hip symptoms years	5(1–8)		6(2–21)		5(5–6)	
Mean ESR at operation	38(22 71)		42(6–104)		32(24–40)	
Involvement of other joints	2nd hip		knees	Feet	Back	
No of patients	26		25	16	18	
ARA functional class	II		III	IV		
No of patients	7		20	3		

FOLLOW-UP

At follow up all the patients were examined by an orthopaedic surgeon, a rheumatologist and a physio-therapist, and X rayed Details of the follow up material are shown in Table 2 Four women with adult rheumatoid arthritis and unilateral hip plasty are excluded from the primary material two owing to severe infection and cup extraction (see above) one owing to pronounced invalidity and one owing to travelling distance

We considered it to be worthwhile to investigate the results of the cup arthroplasties performed in Lund during the period 1966-70 in patients with rheumatoid arthritis, in order to see whether "the cup" was a realistic alternative to the "total hip".

Good operation results with cups have been reported, especially in coxarthrosis (Smith-Petersen 1948, Westerborn 1954, Kelly & Lipscomb 1958, Semb et al. 1960, Aufranc 1962, Harris 1969, Johnston & Larson 1969). The operation has even been used in rheumatoid arthritis, but there are no reports of larger patient materials with this disease and the published results vary considerably. Thus, Johnston & Larson (1969) report good pain relief for all 12 patients with rheumatoid arthritis which they present in their considerable cup material. Aufranc (1962) reports satisfactory results for 82 per cent of 1000 cup arthroplasties, of which 214 were rheumatoids but he gives no percentages for these patients. Kuhns & Potter (1966) report that out of 300 cup arthroplasties 50 per cent were "greatly improved", 25 per cent "moderately improved" whilst 25 per cent were considered "failed", but they do not indicate the number having rheumatoid arthritis

MATERIAL AND METHODS

During the five year period 1966-70, 36 cup arthroplasties were performed on 22 women and 8 men Five women and one man had bilateral arthroplasty The average age of the patients at the time of operation was 44 (15-71) years Age classification and further details of the material are shown in Table 1 It is noted that 23 of the patients could be placed in Steinbrocker's functional class III or IV Fourteen of the adult rheumatic patients were seropositive and 11 seronegative It is also noted that since 1970 only two cups were performed the total hip replacement being the method of choice

Our indications for operation have been severe pain and reduced function due to contracture and limitation of movement Preoperatively the patient has undergone special muscular strength training and contracture treatment

Smith-Petersen's method was used with anterior incision In all cases the iliopsoas tendon was transferred to the ventro lateral capsule remnant and a tenotomy of the adductor muscles was performed The postoperative treatment followed a detailed schedule according to Aufranc (1963) and the patients were allowed full weight-bearing after 6 months from the date of operation The patients then continued with a special training program Average time in hospital was 49 days Twenty eight of the arthroplastics were performed by the same surgeon (H Brattstrom)

Complications Two women with unilateral operation were infected, which later led to extraction of the cups The infection cleared and the patients now have a fibrous anchylosis with satisfactory functional result The youngest patient in the material, a 15-year old boy, had a supracondylar fracture of the femur in connection with the operation This complication was attributed mainly to a pronounced

osteoporosis of the leg There were no diagnosed cases of thrombosis, lung embolism or heart complications In three women with four hip plasties supplementary *dorsal* synovectomy or removal of osteophytes was performed one to two years after the plasties Aufranc (1962) and Johnston & Larsson (1969) report that revision was required in one third of the rheumatic cases, i e rather more frequently than in other patients

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	Juvenile	Adult	Bechterew
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No of patients	26	25	16	18

ARA functional class	II	III	IV
No of patients	7	20	3

FOLLOW UP

At follow up all the patients were examined by an orthopaedic surgeon, a rheumatologist and a physio-therapist, and X-rayed Details of the follow up material are shown in Table 2 Four women with adult rheumatoid arthritis and unilateral hip plasty are excluded from the primary material, two owing to severe infection and cup extraction (see above) one owing to pronounced invalidity and one owing to travelling distance

Table 2 Follow up study, cup arthroplasty

No of patients	26 (18 female, 8 male)		
No of hips	32 (23 female, 9 male)		
Mean observation time	2¾ (2–5¼) years		
Type of arthritis	*Juvenile*	*Adult*	*Bechterew*
No of patients/hips	3/6	21/23	2/3
Mean ESR, mm	12(3–20)	46(17–76)	80(21–115)

RESULTS

The patient's subjective conception of the operation is shown in Table 3 The majority of patients had obtained considerable relief from pain (Figure 1) Rest pain was almost completely eliminated whilst pain on movement was greatly reduced and pain on weight-bearing moderately reduced Thus, preoperatively 19 hip joints had severe pain on weight-bearing and 8 moderate, whereas the corresponding values in the follow-up were reduced to two and seven respectively

Table 3 Patients own opinion on the result of operation (no of hips)

Highly satisfied	3
Satisfied	16
Uncertain	12
Dissatisfied	1
	32

On an average the patients had obtained a slight increase in the total range of motion in the hip Preoperatively the mean value for the sum of flexion, abduction, adduction and rotation was 89°, and 112° at the follow-up Usually preoperatively registered contractures had not improved, i e a preoperative flexion and/or adduction contracture in the hip joint had a strong tendency to recur Altogether 23 hips had obtained relief from pain and improved mobility, 8 hips relief from pain but poorer mobility and one hip increased pain but improved mobility, since the operation

X-ray examination

Bone absorption round the cup and especially on the collum side was seen in 20 hips, 7 of which were described as mild, 9 as moderate and 6 as severe Periarticular calcification or new bone formation was seen in

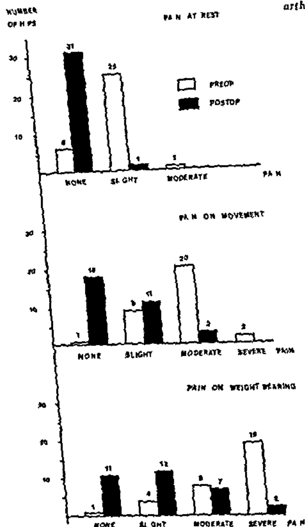


Figure 1 Effect of cup arthroplasty on pain

15 hips and the appearance of acetabular osteophytes in 8 hips A successive change of the postoperatively registered cup position during the observation period was seen in most patients Thus, 13 hips showed a difference of at least 20° in the abduction adduction direction on the anterior posterior exposure, compared with the films taken postoperatively The bone absorption round the cup was not correlated to the patient s age or the use of cortisone therapy No connection between the roentgenographic and clinical appearance was found i e a good

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had juvenile rheumatoid arthritis, two patients with three hip joints had pelvo-spondylitis and the rest had adult rheumatoid arthritis A total of 26 patients (18 women and 8 men with 32 cup arthroplasties) have been followed during an observation period of 2–5½ years Cup arthroplasty was found to have a good effect on pain

The majority of hips had a slight increase in their total range of movement X ray examination showed a considerable bone absorption round the cup in two-thirds of the cases Both cases of pelvo-spondylitis were classified as failures The authors conclude that cup arthroplasty may be an alternative method of treatment to total hip replacement in younger rheumatics i e under 40 years of age, if the surgeon is well acquainted with the technique Compared with total arthroplasty, cup arthroplasty is technically more demanding requires longer hospitalization regular training of the patient for many years and good upper extremities

ACKNOWLEDGEMENTS

This investigation was financially supported by Alfred Österlunds Stiftelse Riksföreningen mot Reumatism and Stiftelsen Konsul Thure Carlssons Minne

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SICOT 12 Abstracta 1972

position of the cup by no means indicated that the patient was free from distress

DISCUSSION AND CONCLUSION

Both patients with pelvo-spondylitis (3 hips) were classified as failures, one owing to pronounced contractures and the other (2 hips) owing to recurrence of synovitis in the hip joints with moderate pain on weight bearing and a very high activity of the disease Both these patients have had successful total hip replacements

Another 7 patients (7 hips) were classified as failures because of moderate or severe pain All 7 patients had remarkably good mobility at follow-up In three hips the joint pain was caused by increased general activity of the disease and recurrence of the synovitis, as seen at reoperation (total hip replacement)

The mean age for six of these failures was 58 years (46 66), the seventh, a female, being only 30 years old So if in this material the age limit between cup arthroplasty and total hip replacement had been 45 years and the cases with pelvo-spondylitis had been excluded, the cup arthroplasty would have been successful in 16 out of 17 hips But the results obtained cannot be compared to the almost total relief of pain and good mobility obtained by total hip replacement The cups require longer hospitalization and a more qualified physical aftertreatment and a surgeon who is familiar with the technical problems of the operation In addition, there is a risk of overloading of the upper extremities during the longer period of non weight-bearing

The best results of cup arthroplasty can be expected in the young patient with good upper extremities, well-preserved joint movement and muscle function A younger patient should be better able to cope with the postoperative treatment, the continuous training and contracture prophylaxis, necessary for lasting results Knowledge of the consequences for the upper extremities and the good results of a possible secondary total hip replacement may make a shortening of the long non weight-bearing period possible

SUMMARY

In Lund, cup arthroplasty has been performed on 30 rheumatic patients (36 hips) during the period 1966–70 Three patients with six hip joints

had juvenile rheumatoid arthritis two patients with three hip joints had pelvo-spondylitis and the rest had adult rheumatoid arthritis A total of 26 patients (18 women and 8 men with 32 cup arthroplasties) have been followed during an observation period of 2 5½ years Cup arthroplasty was found to have a good effect on pain

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FOLLOW-UP OF LOWER-LIMB AMPUTEES

VAGN KOLIND-SØRENSEN

Accepted 7 v 73

The object of the present follow-up study was to elucidate the causes of lower-extremity amputation and to investigate how often the amputees are free of pain and able to walk

MATERIAL

During the period 1967 71 a total of 121 above the knee and below the knee amputations were carried out in the Surgical Department F of the Arhus Municipal Hospital In 12 of these cases bilateral amputation was performed, so that the number of patients was 109

The cause of the amputation was arteriosclerosis in 74 patients co existing in 31 with diabetes mellitus In 18 patients the amputation was done because of emboli All the latter patients had previously undergone operation in the Department of Vascular Surgery and were transferred to us for amputation In practically all the remaining 17 cases the amputations were done because of trauma

The patients attended follow up in 1972

METHOD

The chief principle in selecting the amputation level was to perform primarily below the knee amputation on patients having a normal skin on the middle of the lower leg If cutaneous changes were present or if no bleeding occurred from skin edges or muscles during the operation, the amputation was done above the knee Old and frail persons who should preferably not be subjected to operation more than once and whose prospects of being able to walk again were meagre, were treated by primary above the knee amputation If a stump failed to heal, local revisions and non weightbearing with bed rest were used If this failed and if the necrosis of the stump progressed re amputation was done above the knee

In a number of cases preoperative determination of blood circulation in the anterior tibialis muscle was carried out, using Xenon133

The surgical technique was anterior and posterior skin muscle flap with myoplasty Postoperatively the patients were fitted with an elastic stump bandage and were made to do joint mobilizing and contracture prophylactic as well as generally

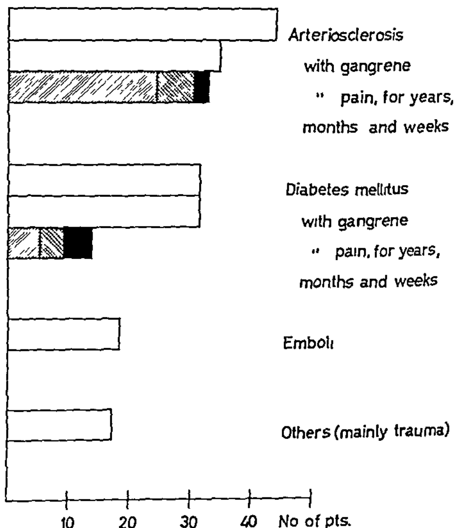


Figure 1 Cause of amputation and preoperative occurrence of gangrene and pain

rehabilitating exercises, but weightbearing was not allowed As soon as the stump had healed and was of a suitable shape, measurements were made for a prosthesis, if the general condition permitted this

RESULTS

The causes of amputation as well as the preoperative occurrence of gangrene and pain may be seen from Figure 1.

Figure 2 gives the postoperative mortality

Among the patients who survived the first postoperative weeks a total of 63 amputations were in the group arteriosclerosis-diabetes Fourteen of these amputations were above and 49 below the knee In 3 instances reoperation was done on the lower leg at a somewhat higher

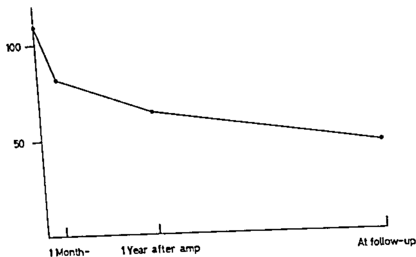
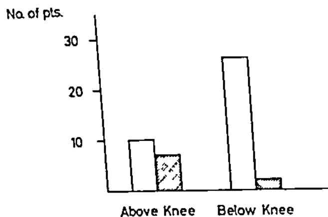


Figure 2 Number of survivors



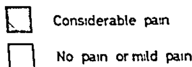


Figure 3 Pain

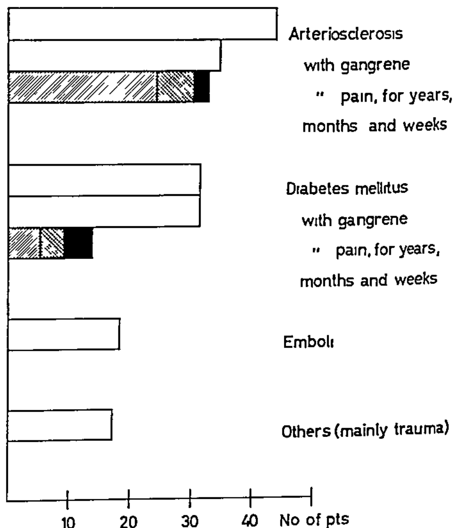


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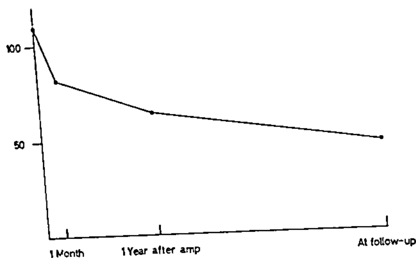
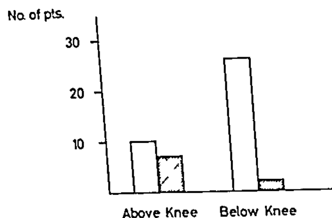


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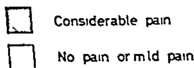


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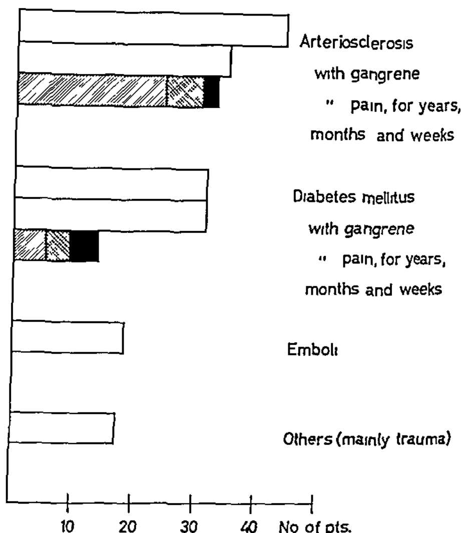


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the prosthesis 7 could walk around a bit indoors whereas 16 were confined to a wheelchair or bed The relation of walking rehabilitation to the amputation level is apparent from Figure 4

DISCUSSION

Most analyses of amputees have shown almost equal numbers of arteriosclerotics and diabetics but during recent years the group of arteriosclerotics has grown larger (Tibell 1971) In the present study too the majority were arteriosclerotics The immediate cause of amputation was gangrene of the foot in most of the arteriosclerotics and in all the diabetics Preoperative pain was more common and had been more long lasting in the arteriosclerotic than in the diabetic patients

Amputation is an operation which carries a high mortality (Lindholm 1964 Ingsig Krarup 1963 Lindahl & Bolund 1969) In the present material the postoperative mortality was 25 per cent and at follow up more than half the patients had died The mortality was affected by the relatively large number of patients with embolism who were transferred for amputation from the Department of Vascular Surgery These patients had the highest mortality and were from a larger geographic area than the others The higher mortality among patients with embolism is also apparent from Tibell s study (1971)

According to the literature phantom pain is present in about half the patients (Funn 1948 Cronholm 1951) more often in those who have had above the knee amputation Freedom from pain must be considered of more importance than walking rehabilitation as an old patient without pain can lead a tolerable life in a wheelchair In the present material half the patients had pain but the pain was severe in only one-fifth Severe pain was more common among patients who had had above-the-knee amputation than in those amputated below the knee The difference is significant Severe pain is taken to mean pain unchanged or aggravated since the operation and present almost constantly In some cases it was reported to be worse than the ischaemic pain from which the patient had suffered prior to the operation Milder pain was periodic and had been decreasing since the operation

Most analyses have shown that only about half the elderly amputees succeed in learning to walk with a prosthesis (Bertelsen & Ronn 1960 Block & Whitehouse 1963 Hansson 1964 Vankka 1967) but during recent years better results have been obtained (Burgess et al 1971) In the present material a full walking ability was attained by half the

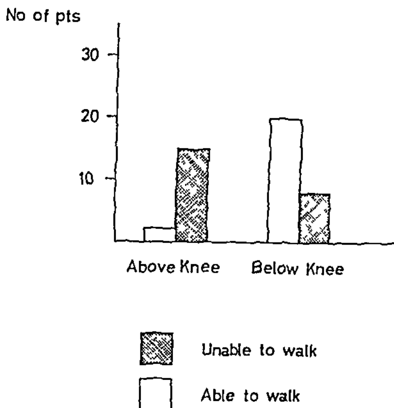


Figure 4 Walking ability with prosthesis

level, whereas in 9 cases secondary amputation, this time above the knee, was done because of absence of wound healing Thus, in 40 cases healing of a lower-leg stump and in 23 cases healing of a femoral stump was obtained

In the embolic group 13 amputations were done, all above the knee The remaining 14 amputations were carried out, in practically all cases, because of trauma Five were above and 9 below the knee No re-amputations were done in this group

Blood circulation in the anterior tibialis muscle, assessed by the Xenon[133] method, showed an average circulation of 16 ml/100 g muscle in the patients who later underwent above-the-knee amputation and of 24 ml in those who later underwent below-the-knee amputation However, individual differences were marked

Out of the 45 patients alive at follow-up 23 reported that they were free of pain, whereas 13 had fairly mild pain and 9 considerable pain In nearly all cases there was a question of phantom pain The relation of the pain to the amputation level may be seen from Figure 3

Among the patients alive at follow-up 22 moved about freely using

the prosthesis 7 could walk around a bit indoors whereas 16 were confined to a wheelchair or bed The relation of walking rehabilitation to the amputation level is apparent from Figure 4

DISCUSSION

Most analyses of amputees have shown almost equal numbers of arteriosclerotics and diabetics but during recent years the group of arteriosclerotics has grown larger (Tibell 1971) In the present study too the majority were arteriosclerotics The immediate cause of amputation was gangrene of the foot in most of the arteriosclerotics and in all the diabetics Preoperative pain was more common and had been more long lasting in the arteriosclerotic than in the diabetic patients

Amputation is an operation which carries a high mortality (Lindholm 1964 Engsig Krarup 1963 Lindahl & Bolund 1969) In the present material the postoperative mortality was 25 per cent and at follow up more than half the patients had died The mortality was affected by the relatively large number of patients with embolism who were transferred for amputation from the Department of Vascular Surgery These patients had the highest mortality and were from a larger geographic area than the others The higher mortality among patients with embolism is also apparent from Tibell s study (1971)

According to the literature phantom pain is present in about half the patients (Lunn 1948 Cronholm 1951) more often in those who have had above the knee amputation Freedom from pain must be considered of more importance than walking rehabilitation as an old patient without pain can lead a tolerable life in a wheelchair In the present material half the patients had pain but the pain was severe in only one fifth Severe pain was more common among patients who had had above the knee amputation than in those amputated below the knee The difference is significant Severe pain is taken to mean pain unchanged or aggravated since the operation and present almost constantly In some cases it was reported to be worse than the ischaemic pain from which the patient had suffered prior to the operation Milder pain was periodical and had been decreasing since the operation

Most analyses have shown that only about half the elderly amputees succeed in learning to walk with a prosthesis (Bertelsen & Ronn 1960 Block & Whitehouse 1963 Hansson 1964 Vankka 1967) but during recent years better results have been obtained (Burgess et al 1971) In the present material a full walking ability was attained by half the

patients, i e these patients moved about freely out of doors, indoors, and on stairs One-sixth were able to walk about a bit indoors, as a rule with two sticks, whereas the remaining third were confined to a wheelchair There was a significantly larger number obtaining full walking ability among the below-the-knee than among the above the knee amputees

To afford freedom from pain as well as a walking ability, then, healing of a below the-knee stump is of decisive importance In the literature below-the-knee amputations are stated to make up less than half of the lower-extremity amputations (Jansen 1960, Dale & Jacobs 1962, Hansson 1964, Kelly & Jones 1970, Kolind-Sørensen 1970), but by the use of a special technique Burgess (1968, 1971) succeeded in obtaining healing of the below-the-knee stump in three-quarters Secondary amputation was carried out in less than 10 per cent of Hansson's (1964) and Burgess et al 's (1971) cases

In the present material healing of a below-the-knee stump was obtained in 63 per cent of the arteriosclerotic-diabetic group—after a secondary above-the-knee amputation had been carried out in 14 per cent

Determination of blood circulation in the anterior tibialis muscle by radioactive Xenon afforded no guidance as to the amputation level

CONCLUSION

Arteriosclerotic patients had more often than diabetic patients a history of long-lasting pain prior to the amputation The immediate cause of the amputation was gangrene in all the diabetics and in three-quarters of the arteriosclerotics

The mortality was high, and only half the patients were surviving at follow-up 1–5 years after the operation

Two thirds of the survivors were able to walk with a prosthesis, but only half of them could be said to have attained a full walking ability The walking ability was far better among the below-the-knee than among the above-the-knee amputees, and this is in accordance with previous findings

Freedom from pain was found in half the patients, but four-fifths were free of severe pain Freedom from pain was also obtained more commonly after below-the knee amputation True, this has also been demonstrated previously, but is perhaps less well known

Therefore, below-the-knee amputation, when possible, is preferable

also in old and frail persons, even though the prospects of attaining walking ability are slight

Among the vascular amputees (except in the embolic patients) healing of a below the-knee stump was obtained in three-fifths Secondary above the-knee amputation had been carried out in one seventh

SUMMARY

A follow up of 109 patients who underwent lower extremity amputation at the Arhus Municipal Hospital during the period 1967–71 is reported

Arteriosclerotic patients had more often than diabetic patients a history of long lasting pain prior to the operation

There was a high mortality, postoperatively as well as in the subsequent years

Among the patients with arteriosclerosis and diabetes 63 per cent obtained healing of a below-the knee stump

Of the survivors about one fifth had considerable pain and about half were unable to walk satisfactorily with a prosthesis

The above the-knee amputees were significantly worse off than the below-the knee amputees in both respects

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A SPECIAL COMPRESSION BANDAGE IN THE TREATMENT OF VARICOSE ULCER OF THE LEG

O Scholsbo D Zdravkovic & K Harbi Sorensen

Accepted 5 xi 73

In 1953, Cocket & Jones demonstrated, that the skin and subcutaneous tissue on the inner side of the ankle and lower third of the leg the so called ulcer area is drained exclusively through short communicating veins which empty directly from the capillary area in the subcutaneous tissue into the posterior tibial vein Thus this area is not drained by the saphenous systems In venous valvular incompetence the blood flows from the deep veins into the subcutaneous tissue, making the capillary pressure very high, in the erect position about 120 cm H_2O (Bauer & Hæger 1962), which is higher than the arteriolar pressure This entails oedema with tissue anoxia and necrosis in the subcutaneous tissue gradually involving the skin leading to fully developed varicose ulcer of the leg (Dodd 1964, Hansson 1964, Sørensen 1964) Incompetence of communicating veins is the most common cause of ulcer Incompetence of the saphenous vein may also lead to the development of an ulcer in some cases (Dodd 1964 Sørensen 1964)

Therefore causal therapy in the preoperative management of the ulcer must consist in reducing the excess venous pressure and keeping away the oedema (Arnoldi 1959 Gundersen 1965, Sjoberg 1965 Sørensen 1965) This may be done by prolonged bed rest with elevation of the limb either at home or in hospital However, this is best avoided because of the risk of thrombosis and because many of the patients are elderly Local treatment of the ulcer and compression bandages are used instead either zinc gelatin bandage, tensoplast bandage or elastic bandage applied from the toes to the knee, in combination with local ulcer therapy (Arnoldi 1959, Bauer & Hæger 1962, Dodd 1964, Gundersen 1965 Hansson 1964 Sjoberg 1965, Sorensen 1964) The zinc gelatin and tensoplast bandages are designed to be worn for up to 4 weeks and therefore can be applied only by specially qualified and



Figure 1 Special compression bandage applied to the leg

trained staff This makes it difficult to clean the ulcer and consequently causes a bad smell embarrassing to the patient and his surroundings

METHOD

At the Department of Orthopaedic Surgery O of the Odense Hospital we have been using a special kind of compression bandage since 1965 It consists of a 20 cm long *cylinder of paper crepe 2 cm in diameter and enclosed in Tubegauze®* *After the* ulcer has been cleaned it is covered with a thick layer of gauze but no hydrophobic layer and no medication The pad is applied behind the tibia from the tip of the medial malleolus and upwards viz on a level with the communicating veins (Figure 1) and the pad is then fixed with an elastic bandage 8 m in length and *8 cm in width from the toes to the knee a particularly large number of turns being* applied around the lower third of the leg in order to prevent the bandage from sliding down (Figure 2) After brief instructions the patient is able to apply the bandage himself and the bandage is left on for as long as possible i e until the turns get loose or fluid from the ulcer oozes through—from a few days at the outset *up to 10 days later on The bandage is kept on during the night The patient is seen in the out patient clinic once a month and when the ulcer has been healed* for one month with continued use of the bandage we have empirically the most favourable time for operation and the patient is admitted for resection of the incompetent communicating veins by the method of Dodd et al (1957) At the same *time the saphenous incompetence is treated surgically as a rule by stripping*

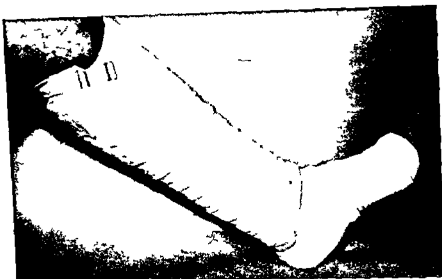


Figure 2 Special compression bandage fixed with elastic bandage

MATERIAL

During the period 1965–1971 a total of 41 patients have been treated by this special compression bandage 14 males and 27 females One patient was treated on both legs The material comprises only purely varicose ulcers Three patients had a history of deep vein thrombophlebitis There were palpable arterial foot pulses on all limbs

Figure 3 gives the age distribution and sex ratio The youngest patient was 30 the oldest 88 Table 1 lists the approximate size of the ulcer in cm² The majority were about one cm² the largest one 70 cm²

Table 1 Area of ulcer

Area cm² (roughly)	Number of extremities		
	Females	Males	Total
1	12	6	18
2	3	2	5
3	4	1	5
6	4	2	6
12	2	2	4
25	3	0	3
70	0	1	1



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were subjected to operation, one refused, and in 3 there were contraindications because of increased operative risk. In all the operated patients the communicating veins were found to be incompetent. A total of 16 patients were overweight, whereas in 25 the body weight was within the normal range.

DISCUSSION

The prerequisite for healing of an ulcer is that the oedema is removed. The compression bandage effectively prevents outflow from the incompetent communicating veins and thereby the development of oedema. Arterial flow improves. It must be expected that the healing time is independent of sex, age, and duration of ulcer. Indeed, there were no statistically significant differences in the duration of ulcer between the two sexes or in the healing time (McWhitney's test $P > 0.05$) and no correlation between age and healing time ($r = 0.28$). There was also no correlation between the healing time and the duration or size of the ulcer ($r = 0.0$).

As the recurrence rate after completed conservative treatment is high, due to the unchanged pathophysiological conditions, the principle must be definitely to treat all patients by radical resection of the communicating veins and operation for saphenous incompetence, provided that their general condition permits this. The smallest number of operative complications occur if the operation is performed about one month after the ulcer has healed, since any inflammatory reaction in the skin and subcutaneous tissue has then as a rule subsided completely.

A special problem is posed by chronic ulcers with firm fibrosis in the surroundings and bed, as this prevents arterial supply to such ulcers. Such cases cannot be treated by the special compression bandage. We excise these ulcers and the entire fibrotic area till healthy tissue is reached and leave the ulcers to granulate before covering them with a split skin graft about two weeks later.

SUMMARY

Forty one patients were treated with a special compression bandage for varicose ulcer of the leg. The ulcers were covered with a thick layer of gauze, and a 20 × 3 cm cylinder of paper crepe enclosed in Tubegauze* was placed behind the tibia, whereupon an 8 m long and

Table 2. Healing time of treated ulcers

Healing time (months)	Number of extremities		
	Females	Males	Total
1	13	3	16
2	5	5	10
3	9	1	10
4	1	4	5
10	0	1	1

RESULTS

All the ulcers healed in 1–10 months, mean 3 2 months, and the majority had healed within 3 months (Table 2).

Of the 41 patients 33 were working during the treatment Twenty-seven reported partial or complete relief of pain in a few days; 3 had local complaints There were 3 recurrences of the ulcer, one after the compression treatment and 2 after operation. Of the 41 patients 37

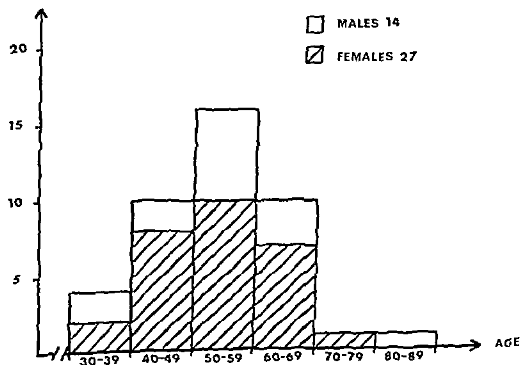


Figure 3 Age distribution and sex ratio of the 41 patients

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The Orthopaedic Hospital Copenhagen Denmark.

OSTEOCHONDRITIS DISSECANS OF THE PATELLA

J Stoi gaard

Accepted 24 v 73

Osteochondritis dissecans of the patella is rare Individual cases have been reported (Carnevale 1953, Cattaneo 1965, De Palme 1954, Heywood 1961, Hutchison 1943, Kleinberg 1949, Marique 1952, Rombold 1936, Schroder 1957, Schultz 1933, and Watson Jones 1955) Almgård et al (1964) reported 2 cases, Lavner (1947) and Pantazopoulos (1971) 4 each, Aichroth (1971) 5, Bauer (1967) 7, and Smillie (1960) 13 cases, 4 or which were bilateral A bilateral occurrence has also been reported by Burns (1959), Hay (1950), Kleinberg (1949), Mageira (1970), Redlich (1969), and Robert & Huges (1950)

Simultaneous involvement of other bones has been described by Hay (1950), Robert & Huges (1950), Smillie (1960), and Watson Jones (1955) Most of these cases have been published at the time that they occurred and therefore without any major follow up period It therefore seemed justified to submit the present material, with special references to late complications

MATERIAL

The material comprises 7 males and 3 females out of approx 400 patients who applied to the Orthopaedic Hospital Copenhagen during the decade 1950–59 with disorders of the knee which were diagnosed as osteochondritis dissecans, osteo chondrosis chondropathy or chondromalacia of the patella

The age at onset of symptoms ranged from 12–21 years and 6 patients were in the age range 12 14 The majority presented within the first year after the onset of symptoms but in 2 cases 2 and 3 years had elapsed

A family history was elicited in the case of a 12 year old girl with bilateral changes Figure 1) whose father had osteochondritis dissecans of both elbows and knees None of the patients had osteoch [illegible]

A 14 year-old boy [illegible]
arthrodesis before the [illegible]
by trauma A 14 yea[illegible] presented primarily with pain in the right knee X rays of the right hip revealed a slipped epiphysis at the femoral head and it was not until epiphysiodesis on the hip had been performed that the osteochondritis

8 cm wide elastic bandage was applied as compression bandage from the toes to the knee No form of medication was applied to the ulcer and the bandage was changed only if ulcer secretion had oozed through it or the turns had loosened The bandage can be applied by the patient himself after brief instruction With this bandage the incompetent communicating veins behind the tibia in the lower third of the leg are compressed Of the 41 patients 33 were working during the treatment and the ulcers healed in an average of 3 2 months Twenty seven patients reported partial or complete relief of pain in a few days

Statistical calculations were carried out to assess the efficacy of the special compression bandage We found no statistically significant difference in the duration of ulcer and healing time between the two sexes and there was also no correlation between age and healing time which also showed no correlation to the duration or size of the ulcer Radical operation for the venous incompetence was carried out when the ulcers had been healed for one month

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Figure 2 a X ray of the right knee of a 14 year-old girl showing a large irregular defect proximally in the patella
b The same knee 10 years later showing the same defect proximally and moreover exostoses

In all cases the lesion was situated in the cartilage lined part of the patella It was not always possible to locate it to the medial or lateral joint surface but when considering also the operative findings, such a localization was possible except in 2 non operated cases In 2 cases the lesion was proximally situated, laterally in one (Figure 2), not accurately located in the other In one case it was in a central situation Eight cases were distally situated, 6 medially, one centrally, and one of uncertain situation The size of the defect was best assessed in the lateral view in which the height of the joint surface was about 40 mm In 2 cases the defect was 5 mm in height, in 2 cases 10 mm, in 6 cases 15 mm and in one case 25 mm (Figure 3), i e involving from one-eighth to one-half of the patellar joint surface in the lateral view The depth of the osteochondritic lesion was from 2–4 mm, but the deepest lesion involved the entire upper lateral quadrant of the patella, continuing through the entire patella to the anterior cortical membrane In 5 cases there was a fragment in the defect, in one case 2 fragments



Figure 1 a X-ray of the right knee of a 12-year old girl In the lower half of the patellar joint surface a rounded defect and a fragment Similar changes were found in the left knee
b The same knee 10 years later, showing a faint hollow at the site of the previous defect

of the homolateral patella was diagnosed The other 8 patients had no associated diseases

In 5 cases there was a history of trauma, possibly direct to the knee

Symptoms Diffuse pain in the knee joint in all cases Often the pain would be aggravated on weight-bearing with flexed knee and then localized more precisely to the patella Four patients had noticed transient swelling after exertion One patient complained of weakness in the knee Three patients had episodes of locking, possibly due to loose bodies (which were demonstrated at operation in 4 of the cases)

Signs Three patients had effusion in the joint There was no limitation of motion or instability In 4 cases there was severe retropatellar crepitation accompanied by pain in one of the cases Atrophy of the quadriceps muscle was present in 4 cases, amounting to 1 cm in 2 cases 2 cm in one case and 3 cm in one case

RADIOGRAPHIC CHANGES

X-rays revealed in all cases an osteochondritic lesion in the patella, most clearly in the lateral view, more rarely in tangential views, and only in one case in the anteroposterior view



Figure 4 a X-ray of the left knee of a 14 year-old boy showing a large defect in the lower half of the patella and at least 2 fragments in the defect
b The same knee, 10 years later, showing smoothing of the defect, exostoses at the apex of the patella and some sclerosis

operations on the meniscus with active movements a few days after the operation Three cases were treated by non-weight-bearing and a posterior splint for 4 weeks

FOLLOW UP

Nine out of the 10 patients (the 10th was living abroad) were seen at follow-up, including radiographic examination, 8–18 years after the primary investigation

All the patients were then working, but 4 of the males had been rejected for military service because of their knee disorder

Four patients reported no symptoms Three had periodical pain in the knee joint on exertion and complaints on flexion for a long time The latter complaint was present also in the patient with bilateral involvement One patient had a tendency to swelling of the knee joint There were no cases of locking incidents

Three patients had a feeling of weakness and instability in the joint.



Figure 3 a X-ray of the right knee of a 16-year-old boy showing an irregular defect, incipient formation of exostoses, and sclerosing of the patella as well as mild changes on the femoral surface of the patella
b The same knee, 14 years later, showing some smoothing of the edges, but increasing exostoses proximally on the patella

(Figure 4), and in 4 cases a loose body in the suprapatellar pouch No radiographic changes were found in the femur or tibia in any case

TREATMENT

Pain, locking incidents, and the demonstration of loose bodies were the factors of most importance in deciding upon operative treatment In 3 instances these complaints seem to have been so modest that no treatment was instituted, even though these 3 cases included the one with the largest defect Eight patients underwent operation consisting of removal of a loose body and curettage of the lesion

In 5 cases moderately severe cartilaginous degeneration was found on the patella, in one case mild changes on the femur In 3 cases the synovial membrane was thickened, purple, and with an increased vascular pattern The postoperative course was uneventful in all the cases After-treatment was in 5 cases the ordinary regimen used after

ous retropatellar crepitation and pain during the examination had given rise to a suspicion

The radiographic changes were pronounced, showing bone defects of the joint surface from 5-25 mm on the lateral view, and usually localized distally and medially This is in keeping with Smillie's findings (1960), whereas a number of others, int al Pantazopoulus (1971) have found the lesions to be localized laterally

Differential diagnostic problems consist of bipartite patella and osteochondral fracture The former is usually painless, the changes are in most cases localized in the upper lateral corner of the patella and do not give rise to the formation of loose bodies A fracture presupposes an adequate trauma, possibly with haemarthrosis Acute operation will show a fresh fracture surface In older cases it may be impossible to distinguish between the two conditions

Treatment was operative in 8 cases No conclusions will be drawn concerning the treatment However, it may be stated that Almgård et al (1964), among others, found less favourable results in cases where the operation included curettage of the crater

Follow up after 8–18 years showed radiologically visible changes of the bone In most cases the defect had rounded edges, but exostoses on the patella had appeared, most often distally, as well as sclerosing of the bone profound to the defect In 3 cases changes were found in other parts of the knee joint The finding of retropatellar crepitation at follow up in 8 cases and pain during that examination in 5 cases would seem to indicate intra articular changes

It must be concluded therefore, that in addition to the acute symptoms an osteochondritic lesion of the patella most often gives rise to persistent radiological changes, in some cases possibly incipient osteoarthritis

In addition, a number of the patients have major or minor symptoms and signs

SUMMARY

A material of 10 patients with osteochondritis dissecans of the patella is submitted The condition was bilateral in one case The defect [illegible] on the X ray films [illegible]
the patella At foll[illegible]
changes of the pat[illegible] of the patients incipient arthritic changes

Four complained of tenderness of the patella on pressure and after minor traumas

Physical examination revealed in 8 cases unmistakable, marked retropatellar crepitation, and 5 of these patients felt severe pain during this examination Only 2 patients had femoral atrophy of 2 and 3 cm respectively

X-rays showed changes at the site of the osteochondritic lesion in all cases, least marked in the female patient with bilateral involvement (Figure 1) In her case there was only a faint hollow on a level with the previous affection The remaining 8 had a major or minor defect, as a rule with a smooth base and rounded edges In two cases the lateral view displayed a somewhat undulating surface The case with the largest defect (Figure 3) still showed distinct changes involving the proximal two thirds of the patella, with an irregular base, somewhat smoothed edges, and exostoses along the patellar margin In the crater there were 2 small fragments The bone profound to the defect was sclerosed

Exostoses along the patellar margin were found in 7 cases Exostoses of a size of 1–2 mm were found proximally in 3 cases, distally in 5, medially and laterally in 2 each In 3 instances the exostoses were from 2 4 mm The bone profound to the defect showed, as already mentioned, some sclerosis, most marked in the case with the large defect, less marked in 3 cases

In one case there were irregularities of the femoral joint surface facing the patella Two cases exhibited mild arthritic changes in the femoro-tibial joint

Owing to the small number of cases, no attempt was made to compare the late results in non operated and operated cases It may be mentioned, however, that the 2 cases showing the most marked exostoses on the patella were among the non-operated ones

DISCUSSION

Osteochondritis dissecans of the patella occurs around puberty, in the present material perhaps somewhat later than similar changes elsewhere in the knee joint and in the elbow The question concerning a traumatic origin cannot be decided on the basis of the present material

The diagnosis was made most accurately on the basis of the X-ray films, although locking incidents, a palpable loose body, and simultane-

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Orthopaedic Hospital University of Arhus Denmark

THE INFLUENCE OF THE INTACT FIBULA ON THE COMPRESSION OF A TIBIAL FRACTURE OR PSEUDOARTHROSIS

Torben Eising Jorgensen

Accepted 25 v 73

For many years the resection of 2 to 3 cm of the middle part of the fibula has been a well recommended treatment of tibial pseudoarthrosis (Sorensen 1969) Even primary resection of the fibula has been recommended at isolated tibial fractures The principle of this was to eliminate the fibular traction on the tibial fragments by resecting the fibula

In many cases of tibial pseudoarthrosis the resection resulted in healing of the fracture although it was a delayed healing Very little is known about the importance of the fibula as regards the entire stability of the [illegible] Tha [illegible]
likely that the [illegible]
the tibia part [illegible]
From a theoret[illegible] point of view the resection of the fibula is not advisable

The aim of this study is to examine the compressibility of a tibial fracture with intact fibula when the fracture is exposed to an increasing compression in the longitudinal axis The decrease of the fractural gap indicates when a compression osteosynthesis is able to adapt a tibial fracture without resection of the fibula

The description of bone tissue as a physical material is rather complex The physical properties differ strongly with the location of the tissue (Blaimont 1968) with age (Lindahl & Lindgren 1968) and with the immobilization period (Nilsson & Smith 1969)

Based on measurements on autopsy bone and bone pieces Sedlin (196[illegible]) set up a model of a cortical bone Research in this field is still being carried out by several investigators (Burstein et al 1972)

Generally a bone model may be described as follows

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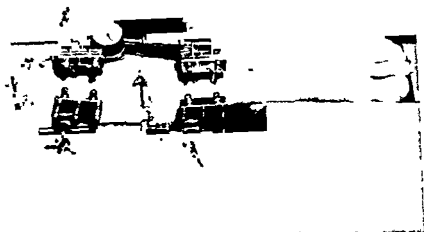


Figure 1 A crural specimen with two sets of Hoffmann's apparatus One of the sets is used for the compression equipment, the other set for the measuring bridge The artifical fracture is shown

and 2) Through a minute transversal incision a 5 mm long piece of the middle of the tibia was removed (Figure 1) The compression bar consists of two steel bars which can be transposed *in parallel to each other* The compression is obtained by means of a spring compressed by an adjusting unit (Figure 3) On the external mantle of the spring a dial shows the force applied The measuring bridge consists of a dial micrometer contacting a pelotte The dial micrometer measures directly the decrease in distance between the two tibial ends, when the compression bar is loaded The measurements were made by initially applying a 5 kgf compression and measuring the immediate decrease *of the tibial* gap Then an identical compression was maintained for 5 minutes whereupon the dial micrometer was re read The compression was gradually increased and the corresponding decrease in the tibial gap was measured both immediately and after 5 minutes The measurements were continued until a compression force of 35 kgf (the maximum force of the compression bar) was obtained

Then the decrease of the tibial gap was examined over 3 hours at a continous compression force of 35 kgf (Figure 4)

RESULTS

1) The fibula exerts a progressive and considerable resistance to the axial compression on the tibia (Figure 4)
2) By extrapolation on the curve of deformation, no immediate de-

When a bone is exposed to a small loading, a deformation will occur. Removal of the load after a brief duration will equalize the deformation completely. By small loadings of brief duration the bone behaves as an elastic body (stress and strain are proportional). A bone loaded by a certain force at once assumes a considerable elastic deformation. During the next 10 minutes a slow after deformation will occur (strain retardation). If the deformation obtained is constant for a certain time, the necessary force will decrease (stress relaxion). Release of the loading leads to a slow decrease of the deformation. If the bone regains its original form, the deformation has been visco-elastic. If not, the deformation has been plastic. Plastic deformation of a bone does not necessarily imply micro-fracture in the bone tissue. This rheologic bone model is based on measurements performed on autopsy specimens. The physical bone properties are influenced by temperature (Sedlin 1965) and by humidity (Smith & Walmsley 1959). The changes occurring in the properties of the bone post-mortem all tend to leave the bone stiff and less elastic. Very few measurements exist on live bone, but measurements of bendings performed on healthy, live tibia confirm the fact that live bone is more bendable and elastic than dead bone (Jernberger 1970). This may be because a live bone is hydraulically strengthened by blood and interstitial liquid, and because the organic phase, represented by long protein molecules in the collagenic fibres, is not coagulated, resulting in rigidity (Knese 1958, Currey 1964, Swanson & Freemann 1966).

Provided closely realistic measurements on dead bones are wanted, these measurements must be performed as quickly as possible post-mortally. In reality no measurements can be made until 6 hours after the occurrence of death. With large amputations it is occasionally possible to measure a fresh specimen, which until recently sustained its normal function.

MATERIAL AND METHOD

The specimen on which measurements were made was a crus from a 17 year-old girl with an osteogenic sarcoma in the middle of the femur. The leg had to be exarticulated at the hip. A few minutes after the exarticulation the crus which was unaffected by the femoral tumour was amputated at the knee joint. The specimen was immediately taken to an examination room with a temperature of 22° C.

On the medial side of the tibia a Hoffmann apparatus with a sliding compression bar was mounted proximally and distally on the tibia so that the tibial bone between the two sets of screws measured 10 cm. Two sets of screws were inserted perpendicular to the first set for the fixation of the measuring bridge (Figures 1

Figure 4 The ratio Diminishing of the artifical fractural gap / Compression force The vertical lines on the curve are due to the delayed deformation of the fibula and ligaments

formation of any considerable size will be obtained by doubling the force of compression (Figure 4)

3) The delayed deformation seems to be considerable and develops constantly for 15 minutes at a maximum compression of 35 kgf Then the rate of deformation decreases gradually for at least 2½ hours (Figure 5)

4) In this case the Hoffmann apparatus was able to transfer a 35 kgf compression to the tibia with intact fibula without appreciable axial shifting (Figure 2)

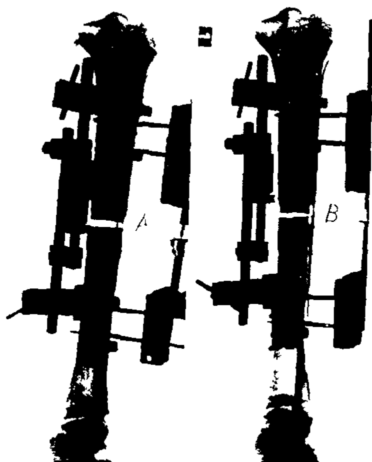


Figure 2 A) X ray of the crural specimen with a fractural gap of 5 mm before compression B) 3 hours after an axial compression of 35 kgf the fractural gap measures 3 5 mm

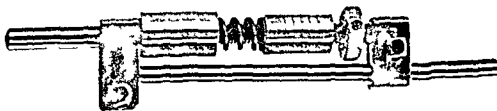


Figure 3 The spring loaded compression bar A dial shows the force applied



Figure 8 The clinical case of a 25 year old pseudoarthrosis

same time X ray showed that the distance between the two screws closest to the fracture was 66 mm An X ray taken one month later showed the same distance and the fracture was healed. Figure 7 shows the curve of stability during the healing time (Jørgensen 1972 e) The healing curve resembles the healing curve of a normal fracture (Jørgensen 1972 b c d) 3½ months after the osteotaxis the fracture presented a stiffness corresponding to that of a normal bone the stabilizing bar was removed and the patient was allowed full weight bearing Follow up measurements one month later showed that the fractural stiffness remained After this the Hoffmann screws were removed and at the clinical check one month later the patient walked with full weight bearing without any complaints

RESULTS

1) From 24 hours to 2½ months after the application of compression on the pseudoarthrosis this seemed to be compressed by 6 mm
2) This pseudoarthrosis showed a healing curve which resembles the

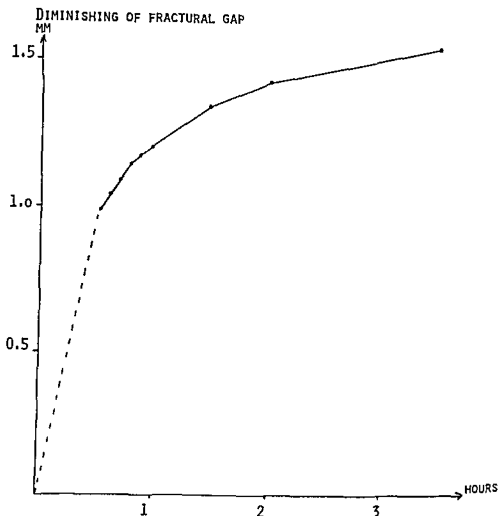


Figure 5 During a constant spring loaded compression for 3 hours the diminishing of the fractional gap slowly decreases due to the increasing resistance of the fibula and ligaments

CLINICAL CASE

A 21-year-old man fractured the left crus, which was treated with 2 Rush pins and plaster for 6 months Twelve months after the accident the material for the osteo synthesis was removed During the following 18 months a clinical pseudoarthrosis developed in the fracture The patient was transferred to the Orthopaedic Hospital, where X-ray revealed a hypertrophical pseudoarthrosis and a healed fibular fracture (Figure 6) Osteotaxis was performed with approximately 30 kgf axial compression on the tibia An X-ray taken 24 hours after the osteotaxis revealed that the distance between the two screws closest to the fracture was 72 mm At intervals of one to two weeks the compression bar was tightened to secure maintenance of the compression 2½ months after the osteotaxis, the compression bar was replaced by a single steel bar, which only fixed the fracture without compression At the



Figure 6 The clinical case of a 2.5 year old pseudoarthrosis

same time X ray showed that the distance between the two screws closest to the fracture was 66 mm An X ray taken one month later showed the same distance and the fracture was healed *Figure 7* shows the curve of stability during the healing time (Jørgensen 1972 *c*) *The healing curve resembles the healing curve of* a normal fracture (Jørgensen 1972 *b c d*) 3½ months after the osteotaxis the fracture presented a stiffness corresponding to that of a normal bone the stabilizing bar was removed and the patient was allowed full weight bearing Follow up measurements one month later showed that the *fractural* stiffness remained. After this the Hoffmann screws were removed and at the *clinical* check one month later *the patient walked with full weight* bearing without any complaints

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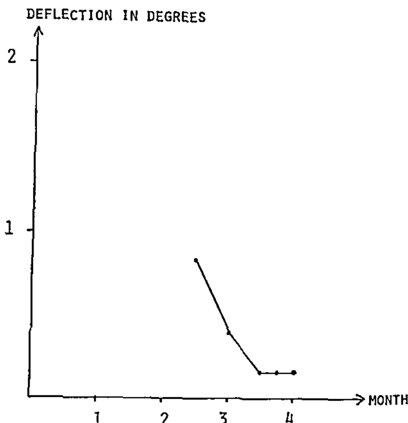


Figure 7 The healing curve of the pseudoarthrosis The curve is obtained by measuring the fractured stiffness or deflection at a known moment of bending

curve of a rapidly healing fresh fracture, estimated from the stiffness

3) The pseudoarthrosis healed rapidly without resection of the fibula

DISCUSSION

The absolute figures in the measurements on the crural specimen must be taken with a certain reservation as the measuring bridge employed was rather crude However, X-rays taken before and after the compression indicate that the measurements are reliable (Figure 2) The measurements show that the fibula and the ligaments exert a very vigorous immediate resistance on compression of the tibia This resistance is somewhat reduced after 2½ hours The resistance measured is sufficient to explain the fact that even the smallest diastasis of a few millimetres in an isolated tibial fracture will require a very great, brief compression force to be eliminated The necessary compression

force may very easily exceed the normal muscular tonus, which acts compressively on the tibia. Provided a compression plate is used on a tibial pseudoarthrosis with an intact or united fibula the fractural fissure will only be reduced corresponding to the immediate deformation of the fibula and its ligaments. If the fracture is to be compressed more than a few millimetres a considerable part of the force applied will have been spent on the deformation of the fibula and its ligaments. During one or two hours a stress relaxation in the fibula will occur, as well as in the visco elastic pseudoarthrosis. A couple of hours after a compression osteosynthesis with a stiff plate has been applied to a tibial fracture with an intact fibula only a compression of the fracture of a few millimetres has been obtained together with the mechanical stability provided by the plate. Thus one or two hours after the application of the compression the fractural stability will depend only on the properties of the material used for the osteosynthesis. The fractural stability aimed at by exposing the pseudoarthrosis to compression by a stiff plate is thus rather doubtful.

If it is desired to maintain the compression on a tibial pseudoarthrosis with an intact fibula external fractural fixation is employed. This fixation allows a correction of after deformation of the fracture and the fibula. A compression bar with a pre-stressed spring will result in maintenance of the compression force on a visco-elastic fracture and the muscular tonus of the leg is still able to produce an axial compression on the fracture. Acting as a sliding bar, the spring loaded compression bar is slightly unstable in the lateral plane. The bar may be locked however so that it acts as a solid steel bar. It is therefore recommended that the fractured leg should be kept absolutely at rest during the hours or days when the spring is loaded on the compression bar. When the patient is mobilized the compression bar is locked and thus it exerts a static compression.

[illegible]

to [illegible] hour compression the pseudoarthrosis was still compressible. This and other cases show that a pseudoarthrosis on the tibia even when fibula is intact may heal by a single external fixation with compression.

My personal experiences with approximately 150 diaphyseal tibial fractures or pseudoarthrosis are that the [illegible]

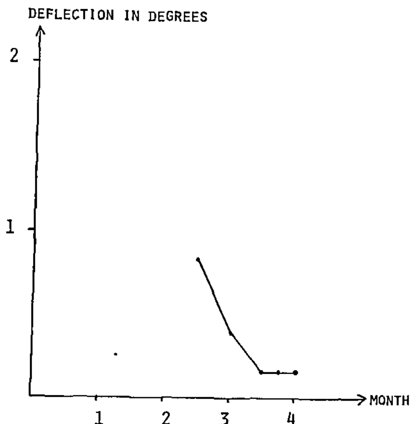


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If it is desired to maintain the compression on a tibial pseudoarthrosis with an intact fibula, external fractural fixation is employed This fixation allows a correction of after deformation of the fracture and the fibula A compression bar with a pre stressed spring will result in maintenance of the compression force on a visco-elastic fracture and the muscular tonus of the leg is still able to produce an axial compression on the fracture Acting as a sliding bar, the spring loaded compression bar is slightly unstable in the lateral plane The bar may be locked however, so that it acts as a solid steel bar It is therefore recommended that the fractured leg should be kept absolutely at rest during the hours or days when the spring is loaded on the compression bar When the patient is mobilized, the compression bar is locked and thus it exerts a static compression

The above mentioned clinical case is one of several treated according to these principles In this case it was found that even after a 24 hour compression the pseudoarthrosis was still compressible This and other cases show that a pseudoarthrosis on the tibia even when fibula is intact may heal by a single external fixation with compression

My personal experiences with approximately 150 diaphyseal tibial fractures or pseudoarthrosis are that the fractures have never been infected through the screw holes in the skin and bone In 15 to 20 per cent of the cases localized secretion from the screw holes may be seen rarely localized bone reaction (Jorgensen 1972 c, Winther & Østerby

1969, Nicoll 1964) Secretion or bone reaction was often caused by loose screws in the bone, either due to faulty technique or mechanical over loading (Jørgensen 1972 d) When the screws were loose, they could usually be removed ambulantly and the screw holes abraded with a small curette without anaesthesia Then the wound healed in 10 days The hospitalization required for the treatment of a pseudoarthrosis in crus amounts to 5 to 10 days *The continued checking of the apparatus* may take place ambulantly every week or every other week

SUMMARY

The object of the present study was to elucidate the problems concern ing resection or no resection of the fibula at a tibial pseudoarthrosis For that purpose a 5 mm long bone specimen was removed from the diaphysis of the tibia on a fresh crus with intact soft parts to represent a pseudoarthrosis By means of a measuring bridge and Hoffmann apparatus with a calibrated compression bar, the reduction of the fractural gap was measured by increasing axial compression on the tibia

The fibula appeared to exert a strong immediate resistance on com pression of the fractural gap (1 mm corresponding to 35 kgf) The resistance slowly decreased during a matter of hours (1 5 mm after 3 hours at 35 kgf)

A tibial pseudoarthrosis with united fibula fracture was treated with osteotaxis a m Hoffmann with an adjustable compression bar From measurements performed on X-rays the pseudoarthrosis was found to be compressed by 6 mm from 24 hours to 2½ months after the osteo taxis

The pseudoarthrosis healed in 3½ months and the healing curve corresponded to that of a normal, rapidly healing fracture

Provided a fibula resection is to be avoided, it is concluded that the employment of an apparatus with adjustable compression is advantage- ous

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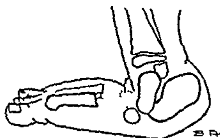
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TREATMENT

The treatment was carried out on an outpatient basis, and consisted of early daily manipulations followed by fixation in a thermoplastic splint made of Plexidur®

The initial manipulations were carried out by specially trained physiotherapists who at the same time gave instruction to the mothers When correction had been accomplished the mothers took over most of the manipulative treatment

For details concerning the different steps of manipulation the reader is referred to the following



INSTRUCTIONS FOR MANIPULATION

First the equinus factor *is treated*

The infant is placed in a prone position on the table *with its* feet towards the physiotherapist The ankle joint is fixed from behind by the homonymous hand with the thumb on the *lateral* and the index finger on the medial malleolus The three ulnar fingers *are placed* on the medial side of the lower *leg*

With the index finger of the heteronymous *hand the* dorsoproximal part of the calcaneus is pressed in a distal direction and at the *same time* the anterior part of calcaneus is pressed in dorsiflexion with the thumb

The following steps are all carried out with the infant in a supine position

The pronation *of the hindfoot* is treated as *follows*

The ankle joint is fixed from *in front by* the homonymous hand the thumb being placed on the med al malleolus

The posterolateral part *of the* calcaneus is grasped with the third *finger of the* he[illegible] hand and [illegible] slight traction pressed *in* supination—the force being increased by the lever action of the heteronymous thumb placed on the homonymous at the medial malleolus acting as the *fulcrum of* this movement

The following steps bring about a *stretching* of the peroneal muscles

The ankle joint is fixed *from in* front with the *heteronymo*

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Acta orthop scand 45 130–144 1974

Orthopaedic Hospital, Copenhagen Denmark

CONGENITAL VERTICAL TALUS

Reevaluation of Early Manipulative Treatment

H Becker-Andersen & I Reimann

Accepted 28 x 73

Vertical talus is a rare congenital foot deformity It is generally agreed that it is difficult to obtain satisfactory correction by non operative treatment In the evaluation of different methods of conservative treatment Lloyd-Roberts & Spence (1958) emphasized that "they have in common an unsatisfactory outcome, because the deformity was neither corrected nor significantly improved in any instance, even when treatment started within the first few weeks of life"

In a clinic with extensive experience with manipulative treatment of congenital club foot, we have made observations concerning early manipulative treatment of vertical talus indicating new possibilities for the conservative form of treatment Thus we feel justified in reporting our preliminary results

MATERIAL

In a special clinic for congenital foot deformities, a total of 648 patients (1053 feet) were seen in the years 1963 1972 Among these 226 cases (341 feet) were idiopathic congenital club feet and only 19 cases (28 feet) were congenital vertical talus Until 1968 all cases of vertical talus were treated by surgical correction

Since our initial experience in 1968 with the first case of vertical talus treated successfully by early manipulation, no infant has been submitted to open reduction, as all early cases were managed successfully by non-operative treatment

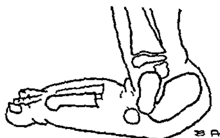
In our following report we have considered only cases of congenital idiopathic vertical talus, thus excluding all cases of myelomeningocele and arthrogryposis

TREATMENT

The treatment was carried out on an outpatient basis, and consisted of early daily manipulations followed by fixation in a thermoplastic splint made of Plexidur®

The initial manipulations were carried out by specially trained physiotherapists, who at the same time gave instruction to the mothers When correction had been accomplished the mothers took over most of the manipulative treatment

For details concerning the different steps of manipulation the reader is referred to the following



INSTRUCTIONS FOR MANIPULATION

First the equinus factor is treated

The infant is placed in a prone position on the table with its feet towards the physiotherapist The ankle joint is fixed from behind by the *homonymous* hand with the thumb on the lateral and the index finger on the medial malleolus The three ulnar fingers are placed on the medial side of the lower leg

With the index finger of the heteronymous hand the dorsoproximal part of the calcaneus is pressed in a distal direction and at the same time the anterior part of calcaneus is pressed in *dorsiflexion* with the thumb

The following steps are all carried out with the infant in a supine position

The pronation of the hindfoot is treated as follows.

The ankle joint is fixed from in front by the *homonymous* hand the thumb being placed on the medial malleolus

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increas [illegible] onymous thumb placed on the homonymous at the medial malleolus acting as the *fulcrum of this* movement

The following steps bring about a *stretching* of the peroneal muscles

The ankle joint is fixed from in front with the heteronymous hand the thumb on the lateral the index on the medial *malleolus* With the thumb of the homonymous hand placed at the level of the 5th *metatarsal* base the forepart of the *foot* is pressed in adduction and slight supination

Stretching of the toe extensors and foot dorsiflexors is the object of the next step The posterior part of the foot is fixed from behind by the heteronymous hand The index of the homonymous hand is placed across the proximal dorsum of the foot which is pulled in plantar flexion

The object of the final procedure is the reduction of the talonavicular dislocation The hindfoot is fixed from behind with the homonymous hand The thumb is placed on the medial malleolus and calcaneus the index and third fingers on the lateral malleolus and calcaneus

The heteronymous hand applies slight traction by means of the index and third fingers placed on the navicular bone the thumb being placed at the level of the head of the talus in the sole of the foot The forefoot is pressed in plantar flexion and slight supination At the same time the head of the talus is pressed in a dorsal direction by the thumb During this particular step the actual reduction of the talonavicular dislocation takes place

CASE REPORTS

Case 1 A girl with right sided vertical talus first seen at the age of eight days The foot was found to have marked dorsiflexion and pronation abduction of the forefoot and the heel was elevated The Achilles tendon was rather tight and there was a marked contracture of the dorsiflexors and the tibialis anterior The peroneal tendons especially the brevis tendon were also very tight (Figure 1 1)

The radiograph (Figure 1 2) showed typical findings in early vertical talus

Treatment was started immediately with daily manipulations followed by fixation in a thermoplastic splint After two weeks of treatment only moderate contractures persisted At the age of four months the foot was completely corrected clinically and the radiograph (Figure 1 3) verified the correction obtained During the first year of life treatment was continued from the age of six months the treatment was given mainly by the mother after appropriate instructions and the result was *checked at the clinic about every three months*



Figure 1 1 Case 1 Girl aged eight days with right sided vertical talus and normal left foot



Figure 12 Case 1 Radiograph eight days old The lateral view taken with the feet in non forced dorsiflexion illustrates the early radiographic findings in vertical talus the vertical position of talus the equinus of the calcaneus and the extreme dorsiflexion and pronation of the forefoot Note the slight hypoplasia of the ossification centres of the tarsal bones in comparison with the normal foot The dorsoplantar view shows extreme abduction of the forefoot

Figure 13 Same case at the age of four months The lateral view shows complete correction the equinus of talus and calcaneus is corrected and normal relation between the axis of the forefoot and the talar axis is established The dorsoplantar view shows correction of the forefoot



Figure 14. Same case at the age of 14 months. Lateral view of the right vertical talus. From left to right the foot is seen without, with weightbearing and during weightbearing in boots. A slight equinus of talus is seen during weightbearing but disappears in boots.



Figure 15. Same case. Lateral view of the left normal foot. Notice the same degree of equinus of talus during weightbearing.



1 2

Figure 2.1 Case 2 Boy at the age of eight days Radiograph lateral view of right sided vertical talus illustrates typical findings with equinus of talus and calcaneus as well as marked dorsiflexion and pronation of the forefoot

Figure 2.2 Same case at the age of $3^{10}/_{12}$ years shows complete correction

It has been of special interest to see that the correction was maintained during weightbearing as seen on radiographs at the age of 14 months (Figures 1 4 and 1 5) The patient was last seen at the age of 15 months and the foot was still found to be completely corrected There was no restriction of mobility in the ankle joint or the subtalar joint

Case 2 A boy with right sided vertical talus first seen at the age of eight days The foot had the typical appearance of vertical talus with rocker bottom deformity, pronounced dorsiflexion pronation of the forefoot and elevation of the heel, the radiograph (Figure 2 1) confirmed the diagnosis Conservative treatment by manipulations and splinting was started immediately During the first two weeks of



1 2

Figure 3.1 Case 3 Boy at the age of four days Radiograph lateral view of right sided vertical talus There is a marked equinus of the talus some equinus of the calcaneus and a marked dorsiflexion and pronation of the forefoot

Figure 3.2 Same case Age nine months shows complete correction



Figures 4.1 & 4.2 Case 4 Boy at the age of three days Radiograph of bilateral vertical talus in lateral view (4.1 right and 4.2 left) Extreme equinus of talus and calcaneus as well as marked dorsiflexion of the forefoot is seen



Figures 4.3 & 4.4 Same case at the age of three months (4.3 right and 4.4 left) Complete correction is seen on both sides

treatment a pronounced improvement of the foot was seen though the correction was still incomplete At the age of three months the foot was completely corrected clinically as well as radiologically it was noticed that no tightening of the Achilles tendon persisted During the first year of life correction was maintained by night splint and occasional manipulations given by the mother No recurrence was seen during weightbearing and at the age of 16 months the foot was found to be so stable that the night splint was discontinued

The patient was last seen at the age of 3 years 10 months the foot was clinically normal, and the radiograph (Figure 2.2) showed complete correction

Case 3 A boy with right sided vertical talus first seen in the age of four days A typical rocker bottom deformity with a marked plantar prominence of the head of the talus was seen The dorsiflexed and abducted forefoot was touching the



1 2

Figures 5 1 & 5 2 Case 5 Boy at the age of 3¾ months Radiograph of bilateral vertical talus Lateral view (5 1 right and 5 2 left) On both sides a marked equinus of talus and *calcaneus* is *seen*



3 4

Figures 5 3 & 5 4 Same case at the age of seven months (5 3 right and 5 4 left) Notice the moderate equinus of talus and calcaneus indicating slight talo navicular subluxation in spite of normal T C angles

anterior tibia The radiograph (Figure 3 1) confirmed the diagnosis During the first week of manipulation a marked improvement was obtained a normal talo-navicular relation was palpated and a distinct medial arch was seen At the age of 3 weeks it was observed that the calcaneus was in a normal position without tightening of the Achilles tendon A radiograph at the age of three months verified *the clinical* impression of complete correction (Figure 3 2)

On the last examination at the age of nine months no signs of a recurrence were seen

the heels were elevated Radiographs (Figures 4 1 and 4 2) confirmed the diagnosis of severe vertical talus After two weeks both feet could be manipulated into complete correction, though a slight abduction-pronation of the forefoot persisted

The patient was last seen at the age of three months, both feet were completely corrected without elevation of the heels, with a distinct medial arch and normal joint mobility Radiographs (Figures 4 3 and 4 4) verified the correction

Case 5 A boy with bilateral vertical talus, first seen at the age of 3¾ months On physical examination the elevation of the heels was the most obvious finding whereas the talar prominence in planta was less pronounced The forefeet were seen to be in dorsiflexion with a corresponding tightening of the dorsiflexors Radiographs (Figures 5 1 and 5 2) showed the typical findings of vertical talus After five weeks of treatment some elevation of the heels persisted due to tightening of the Achilles tendon

The patient was last seen at the age of seven months A distinct medial arch was *seen to be in dorsiflexion with a corresponding tightening of the dorsiflexors* ence of a slight talo navicular subluxation In accordance with this the supination was restricted Radiographs (Figures 5 3 and 5 4) confirmed the clinical findings

DISCUSSION AND CONCLUSION

The treatment of vertical talus is difficult and open reduction is considered necessary in most cases to obtain satisfactory and stable correction (Osmond-Clarke 1956, Lloyd-Roberts & Spence 1958, Herndon & Heymann 1963)

If, however, the condition is diagnosed in the first weeks of life, correction can be obtained by conservative methods A few cases of successful correction by reduction and treatment with plaster of Paris have been reported (Storen 1967, Harrold 1967, Silk & Wainwright 1967)

The early clinical diagnosis seems to be difficult and especially the differential diagnosis between this condition and congenital calcaneo-valgus In both conditions the forefoot is found in dorsiflexion The medial arch is not very well defined in infants and only in more pronounced cases of vertical talus an obvious prominence of the talus is seen in the planta In our experience the elevated calcaneus is the most prominent finding as this is not seen in any of the foot deformities with which vertical talus is likely to be confused

We disagree at this point with Rigault & Pouliquen (1970), who considered the equinus position of the calcaneus an inconstant finding in vertical talus

Table 1 Radiographic angles of the whole series

Case no	Age	T C angle R	T C angle L	T1-T angle R	T1-T angle L	T1-C angle R	T1-C angle L	M T angle R	M T angle L
Case 1									
Lateral view	8 days	70	35	*140*	110	*110*	110	*90*	150
	4 mths	35	30	*100*	110	*120*	100	*160*	175
	12 –	25	40	*95*	95	*110*	130	*175*	160
	14 –	30	40	*110*	95	*100*	125	*170*	165
	14 –	35	35	*115*	115	*100*	105	*155*	160
	14 –	*20*	20	*110*	110	*90*	90	*185*	195
Dorso plantar view	8 days	25	25					*100*	175
	4 mths	25	30					*145*	160
	12 –	35	30					*160*	170
Case 2									
Lateral view	8 days	*50*	40	*130*	95	*105*	130	*110*	150
	1¼ mths	*45*		*135*		*100*		*180*	
	3¼ –	*30*	30	*120*	95	*95*	110	*180*	185
	12 –	*40*	35	*135*	120	*85*	95	*170*	180
	3¾ years	*30*	30	*110*	100	*105*	115	*185*	190
Dorso plantar view	8 days	*50*	60					*120*	115
	3¼ mths	*35*	60					*160*	150
	12 –	*35*	35					155	160
	3¾ years	*30*	30					175	180
Case 3									
Lateral view	4 days	*60*	45	*130*	100	*115*	130	*105*	150
	3 mths	*40*	40	*90*	90	*130*	130	*170*	150
	9	*40*	45	*90*	105	*125*	120	*165*	165
Dorso plantar view	4 days	25	20					*120*	150
	3 mths	30	35					*140*	140
	9	35	20					140	160
Case 4									
Lateral view	3 days	80	60	160	145	*105*	*95*	*60*	*70*
	3 mths	45	35	*110*	*115*	*115*	*110*	140	*160*
Dorso plantar view	3 days	*60*	55					*100*	*120*
	3 mths	40	*40*					*150*	*180*

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The patient was last seen at the age of three months, both feet were completely corrected without elevation of the heels with a distinct medial arch and normal joint mobility Radiographs (Figures 4 3 and 4 4) verified the correction

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The patient was last seen at the age of seven months A distinct medial arch was seen to be in dorsiflexion with a corresponding tightening of the dorsiflexors ence of a slight talo navicular subluxation In accordance with this the supination was restricted Radiographs (Figures 5 3 and 5 4) confirmed the clinical findings

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Table 1 Radiographic angles of the whole series

Case no	Age	T C angle R	T C angle L	T_1 T angle R	T_1 T angle L	T_1 C angle R	T_1 C angle L	M T angle R	M T angle L
Case 1									
Lateral view	8 days	70	35	140	110	110	110	90	150
	4 mths	35	30	100	110	190	100	160	175
	12 –	95	40	95	95	110	130	175	160
	14 –	30	40	110	95	100	125	170	165
	14 –	35	35	115	115	100	105	155	160
	14 –	20	20	110	110	90	90	185	195
Dorso plantar view	8 days	25	25					100	175
	4 mths	25	30					145	160
	12 –	35	30					160	170
Case 2									
Lateral view	8 days	50	40	130	95	105	130	110	150
	1¼ mths	45		135		100		180	
	3¼ –	30	30	120	95	95	110	180	185
	12 –	40	35	135	120	85	95	170	180
	3¾ years	30	30	110	100	105	115	185	190
Dorso plantar view	8 days	50	60					120	115
	3¼ mths	35	60					160	150
	12	35	35					155	160
	3¾ years	30	30					175	180
Case 3									
Lateral view	4 days	60	45	130	100	115	130	105	150
	3 mths	40	40	90	90	130	130	170	150
	9	40	45	90	105	125	120	165	165
Dorso plantar view	4 days	25	20					120	150
	3 mths	30	35					140	110
	9	35	20					140	160
Case 4									
Lateral view	3 days	80	60	160	145	105	95	60	70
	3 mths	45	35	110	115	115	110	140	160
Dorso-plantar view	3 days	60	55					100	120
	3 mths	40	40					150	180

Table 1 (cont)

Case no	Age	T C angle R	T C angle L	Ti T angle R	Ti T angle L	Ti C angle R	Ti C angle L	M-T angle R	M-T angle L
Case 5									
Lateral view	3¾ mths	35	45	130	140	90	95	125	110
	6 –	40	35	120	120	100	90	140	140
	7 –	45	45	135	135	90	95	180	180
Dorso plantar									
view	3¾ mths	30	30					150	150
	6 –	25	35					150	140
	7 –	45	35					150	140

Vertical talus values indicated by italics
T-C angle talo calcanear angle
Ti-T angle tibio talar angle
Ti C angle tibio calcanear angle
M-T angle metatarso talar angle
R right side
L left side

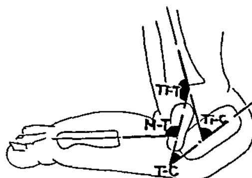


Figure 6 Diagram showing the different angles listed in Table 1

Contrary to Osmond Clarke (1966) we find the radiographic examination of paramount importance for the early diagnosis of this condition In the early radiograph the vertical position of the talus, the equinus position of the calcaneus and the marked dorsiflexion of the first metatarsal bone is obvious Some hypoplasia of the ossification centres of the tarsal bones may occur

The present report concerns a small series of vertical talus treated by manipulations in the first weeks of life Until 1968 we found open reduction necessary in all cases, usually performed at the age of 6 months On the basis of our experience with early manipulative correction of club feet we have found it natural to try the possibility of this treatment also in vertical talus

Our initial experience with case no 2 was surprising, as the deformity was corrected during the first 2 to 3 weeks of treatment and has shown no signs of recurrence during weightbearing At the age of 4 years we still find the foot clinically as well as radiographically normal

During the treatment of subsequent cases we have made the following clinical observations

All cases treated during the first week of life have been equally as easy to correct as our first case Case no 5, in which treatment was started at the age of 4 months, required a more intensive and longer lasting manipulation and the correction is not yet quite complete This course emphasizes the importance of early diagnosis and treatment Once correction has been obtained, none of our cases have shown any signs of recurrence during weightbearing

Patterson et al (1968) have demonstrated the secondary adaptive changes in the tarsal bones in a post mortem study of a 6 weeks old infant The difficulty in obtaining stability of correction which is so often reported (Eyre Brock 1967, Mead & Anast 1961, Outland & Sherk 1960) may be explained by the more pronounced adaptive bone changes after a few months The experimental work of Ritsilä (1969) also indicates that the bone changes are adaptive

The contractures of muscles and tendons were easy to correct compared to the contractures in club foot This also applies to the tendo calcanei The elongation of this tendon which has been mentioned in connection with open reduction after the age of 3 months (Silk & Wainwright 1967) has not been necessary

These findings together with our observations of the rather moderate hypoplasia of the ossification centres of the tarsal bones seems to indicate that the dislocation seen at birth has occurred rather late in pregnancy and probably later than the changes in congenital club foot (Reimann 1967)

The radiographic examination has been valuable not only in the early diagnosis but also in the evaluation of treatment during which we have made the following observations

Though the term vertical talus could give the impression of an increased T C angle in lateral view, it is seen from Table 1 that the values of T C angles are within normal and stay within this range during correction This indicates that the relation between the talus and calcaneus is unchanged during correction Also in dorso-plantar view the T C angles are found to be within normal range

During treatment a decrease of the tibio-talar (Ti T) angle and an

increase of the tibio calcanear (Ti-C) angle would be expected The values of these angles are influenced by the degree of dorsiflexion in the ankle joint This probably explains the variation seen in these values in Table 1

The vertical position of the talus for this reason should be evaluated in relation to the bones distal to the midtarsal joint As seen in the table the metatarso talar (M-T) angle gives a clear expression of the marked changes during the reduction of the talonavicular dislocation The M-T angles increase from values of about 90 degrees before to about 180 degrees after correction

As the ossification centre of the cuboid bone is not seen in radiographs in very early cases the relation of the talar axis to this centre is not recorded in the table

Radiographs during weightbearing have verified the clinical impression of stable correction As seen in Figure 1 4 there is a slight equinus of the talus during weightbearing, but comparison with Figure 1 5 shows the same findings in the unaffected foot It should be emphasized that no equinus of the calcaneus is seen during weightbearing The talus equinus during weightbearing will be seen to be even more marked in the hypermobile valgus foot (Templeton et al 1965)

As seen in Figures 1 4 and 1 5 the equinus tendency of the talus disappears during weightbearing in boots

No radiographic evidence of bone damage caused by the manipulative treatment was observed in this small series We agree with Fjeldborg (1971) that it is essential that manipulation is performed without violence

It is concluded that is has been possible to obtain stable correction of the idiopathic congenital vertical talus by manipulative treatment without anaesthesia if treatment is started during the first weeks of life The protracted course of one case in which treatment was started at the age of 4 months clearly indicates that reduction and stability is more easily obtained when treatment is started as early as possible

SUMMARY

Early diagnosis and early institution of treatment allow the possibility of correction of the congenital vertical talus by non-operative methods

The early clinical diagnosis may be difficult The main differential

diagnosis is the congenital calcaneo valgus It is emphasized that elevation of the heel is an important physical finding but radiographic examination is considered necessary to verify the diagnosis

Based on experience from manipulative treatment of the congenital club foot, a manipulative technique for the correction of the vertical talus has been developed Details of the technique are described

Since 1968 this technique has been applied to all cases with an ensuing reduction There has been no sign of recurrence during weight bearing five cases (7 vertical talus feet) are reported

Radiographic evaluation of the changes during correction shows that the angle between the longitudinal axis of talus and calcaneus is of no value in early diagnosis and in evaluation of correction The equinus of the talus is best seen in relation to the bones distal to the midtarsal joint and in early cases it is best expressed by the angles between the longitudinal axis of the first metatarsal bone and the talar axis (M T angle)

The nature of the contracture seen at birth and the rather moderate hypoplasia of the ossific nuclei indicates that the talonavicular dislocation has occurred rather late in pregnancy

The difficulty in obtaining stable correction must be seen in relation to the amount of adaptive secondary bone changes developed between the time of the intrauterine dislocation and the commencement of treatment

It is concluded that it is possible by early institution of manipulative treatment to obtain complete and stable *correction of congenital vertical talus*

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CONGENITAL CALCANEOVALGUS

With Special Reference to Treatment and its Relation to Other Congenital Foot Deformities

BO LARSEN, I REIMANN & H BECKER-ANDERSEN

Accepted 10 iv 73

Congenital calcaneovalgus is a rather common foot deformity At birth the foot in seen to be lying in acute dorsiflexion with the dorsum of the foot touching the anterior tibia, there is an increased valgus of the hindfoot, and some contracture of the dorsiflexors may be seen It is generally agreed, that most of these cases require no treatment (Wetzenstein 1970, Klassen 1971)

The purpose of the present report has been to evaluate the prognosis of this condition compared to other congenital foot deformities and to estimate if treatment has had any influence on the final result



MATERIAL AND METHODS

During the years 1961–1968, 86 infants with 125 calcaneovalgus feet were seen, among these 39 (45 per cent) were bilateral, 24 right sided and 23 left sided There were 50 (58 1 per cent) girls and 36 (41 9 per cent) boys

At the initial examination within the first weeks of life slight to moderate contractures of the foot dorsiflexors were found in 42 (34 per cent) of the feet

Except for slight insufficiency of the triceps muscle no pareses were found Radiographic evaluation has not been used routinely either in the initial examination or during treatment, thus only 14 of the calcaneovalgus feet were radiographed

Pregnancy and delivery were uncomplicated except for 5 cases of breech presentation and 2 cases of caesarean section

In 6 cases the following associated abnormalities were found 3 metatarsus varus 1 vertical talus, 1 syndactylia and 1 congenital dislocation of the hip

Treatment, consisting in gentle manipulations and elastic bandage, was instituted in 50 per cent of the cases, thus 61 (49 per cent) of the calcaneovalgus feet were treated 57 per cent of the feet with contractures were treated

Duration of treatment was 3-5 weeks

All cases were seen for examination at the age of about 12 months

RESULTS

At follow-up in January 1972, 75 of the cases with 110 calcaneovalgus feet (88 per cent) were seen The age at examination was 3-11 years, 50 per cent of the patients were more than 6 years of age

Among the physical findings our interest was focused upon residual valgus of the hindfoot In order to achieve a numerical expression of this factor the following methods were used

All cases were photographed Prior to this a line was drawn from the midpoint of the heel following the midaxis of the achilles tendon continued in the midaxes

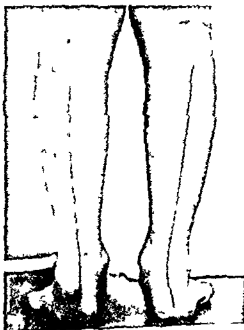


Figure 1 Case no 18 Girl age 8 years with right sided calcaneovalgus Photograph used for measuring hindfoot valgus The deviation of the heel line from the mid axis line of the lower leg is taken as the degree of valgus

of the lower leg This line was drawn with the child lying on its knees and with the foot corrected to neutral position Then the photograph was taken with the child standing with weight on both feet and a few centimeters between the medial malleoli As seen in Figure 1 the degree of the hindfoot valgus is measured as the deviation of the heel line

Subjective complaints were very moderate only 5 children mentioned tiredness and tenderness in the feet after a long walk

Physical examination without weightbearing showed no decreased mobility in ankle or subtalar joint In 5 cases some hypermobility was seen

The medial arch of the foot was normal in all cases

No atrophy or muscular insufficiency or hypoplasia of the feet was seen in any of the cases

No gait abnormalities were found

Physical findings during weightbearing were normal except for some residual valgus of the hindfoot Based on the photographs the material is separated into group 1 with valgus 0 10 degrees and group 2 above 10 degrees 75 per cent (83 calcaneo valgus feet) were found in group 1

Figure 2 illustrates the findings in 40 unilateral cases 45 per cent (18 cases) showed a valgus more pronounced than on the normal side 12 5 per cent showed a slightly decreased valgus

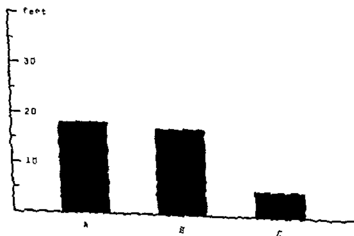


Figure 2 40 unilateral cases of calcaneovalgus compared with the normal side show in 18 (45 per cent) a valgus degree more pronounced than on the normal side (A) in 17 (42.5 per cent) no difference is found (B) and in 5 (12 5 per cent) a slightly decreased valgus is seen (C)

Except for slight insufficiency of the triceps muscle no pareses were found Radiographic evaluation has not been used routinely either in the initial examination or during treatment, thus only 14 of the calcaneovalgus feet were radiographed

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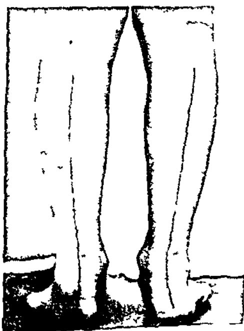


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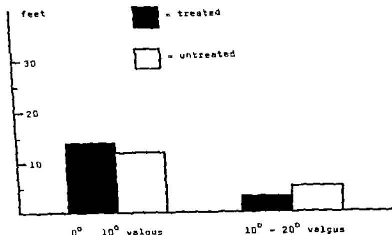


Figure 4 Comparison between treated and untreated cases with contractures 82 per cent of the treated and 71 per cent of the untreated feet show a valgus of 0–10 degrees 18 per cent of the treated and 29 per cent of the untreated show a valgus of 10–20 degrees

Our material shows some confusion concerning the diagnosis as only 13 per cent were referred with a correct diagnosis However the diagnosis should cause no difficulty as the appearance of the congenital calcaneovalgus is so different from other foot deformities Only the rare vertical talus might present problems in differential diagnosis, but it is distinguished by elevation of the heel and the rocker bottom appearance

Congenital calcaneovalgus is the most common foot deformity and when moderate degrees are included an incidence of 30–50 per cent is reported (Wetzenstein 1970) Hereditary predisposition in 68 per cent of cases is reported by Giannestras (1970) Calculations of incidence and hereditary predisposition on the basis of this material have been omitted As many of the cases improved spontaneously within the first weeks of life the results of these calculations have been unreliable

That prognosis as indicated above, is good is generally agreed Most cases end up with completely normal feet, but in some cases this deformity leads to later development of static abnormalities with increased valgus of the hindfoot and in some cases lowered medial arch (Wetzenstein 1970)

After a period of observation of 3–11 years the only abnormal finding

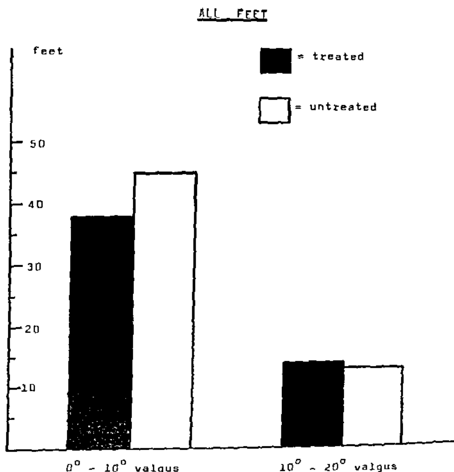


Figure 3 Comparison between treated and untreated cases 73 per cent of the treated and 78 per cent of the untreated feet show a valgus of 0–10 degrees 27 per cent of the treated and 23 per cent of the untreated show a valgus between 10 20 degrees

Comparison between treated and untreated cases showed no difference in the degree of valgus (Figure 3)

As seen from Figure 4 the severity of contractures at the initial examination had no influence on the final result The degree of hyperlaxitas was also examined and in 52 cases (69 per cent) some hyperlaxitas in knees, elbows or fingers was seen

DISCUSSION AND CONCLUSION

Congenital calcaneovalgus is essentially different from other congenital idiopathic foot deformities from the point of view of treatment as well as prognosis

SUMMARY

Based on a clinical material of 86 patients with 125 calcaneovalgus feet the prognosis and the indication for treatment has been evaluated. The age at follow up was 3–11 years. At the initial examination within the first weeks of life 34 per cent of the feet had contractures. Forty-nine per cent of the feet were treated with gentle manipulations and elastic bandages. The average duration of treatment was 3–5 weeks.

At follow up most feet were normalized. Only residual valgus of the hindfoot was seen in some cases, thus 75 per cent had a valgus of 0–10 degrees and 25 per cent had a valgus of 10–20 degrees. In unilateral cases 45 per cent showed a valgus more pronounced than on the normal side.

Comparison between treated and untreated cases showed no difference in the degree of valgus. Also the severity of contractures seen at the initial examination did not influence the final result.

The excellent prognosis compared with other congenital foot deformities is explained by absence of luxation in the hind- and midfoot at birth and consequently no secondary adaptive bone changes have developed.

In the present series no difference was found between treated and untreated cases.

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was increased valgus Among 40 unilateral cases 45 per cent showed a valgus angulation of the hindfoot, more pronounced than on the normal side

The exceptionally good prognosis compared to other congenital foot deformities may be explained by the changes found at birth Though the foot is lying in extreme dorsiflexion with moderate increased valgus of the hindfoot, the contractures found in the foot dorsiflexors and skin are not very pronounced

The most important point however is that no luxation is found This is contrary to findings in congenital club foot (Reimann 1967) and vertical talus This implies that no secondary adaptive bone changes or hypoplasia of the ossification centers are found at birth This is verified by early radiographic findings in this condition

Consequently only a few radiographs have been taken in the present material, all confirming normal findings (Templeton et al 1965)

The absence of luxation and secondary bone changes explains why many cases improve spontaneously Different methods of treatment are reported In cases with marked contractures, Støren (1967) and Giannestras (1970) used corrective casts In cases with moderate contractures manipulations have been used (Støren 1967)

As mentioned by Wetzenstein (1970) no reports of comparative investigations between treated and untreated cases have been published Based on the present series it has been possible to compare treated and untreated cases Among 125 calcaneovalgus feet 49 per cent were treated with manipulations and elastic bandage, 51 per cent of the cases were untreated and followed by regular examinations In the 2 groups 39 per cent and 28 per cent, respectively, had marked contractures At follow-up no significant difference was found between treated and untreated cases, and the severity of the contractures found at birth had no influence on the final results

Based on our experience we find it reasonable in cases with severe contractures (where plantarflexion is restricted to right angle position) to use gentle manipulations to accelerate the course The absence of secondary adaptive bone changes indicates that retention of the foot in a corrected position, for instance in casts, is unnecessary

It is concluded that congenital calcaneovalgus, which is the most common congenital foot deformity, has an extremely good prognosis and that treatment is rarely indicated This is explained by the absence of luxation and secondary adaptive changes at birth This indicates that the deformity occurs late in pregnancy possibly in connection with constitutional hyperlaxity

SUMMARY

Based on a clinical material of 86 patients with 125 calcaneovalgus feet the prognosis and the indication for treatment has been evaluated The age at follow up was 3–11 years At the initial examination within the first weeks of life 34 per cent of the feet had contractures Forty-nine per cent of the feet were treated with gentle manipulations and elastic bandages The average duration of treatment was 3–5 weeks

At follow up most feet were normalized Only residual valgus of the hindfoot was seen in some cases, thus 75 per cent had a valgus of 0–10 degrees and 25 per cent had a valgus of 10–20 degrees In unilateral cases 45 per cent showed a valgus more pronounced than on the normal side

Comparison between treated and untreated cases showed no difference in the degree of valgus Also the severity of contractures seen at the initial examination did not influence the final result

The excellent prognosis compared with other congenital foot deformities is explained by absence of luxation in the hind- and midfoot at birth and consequently no secondary adaptive bone changes have developed

In the present series no difference was found between treated and untreated cases

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DRILLING OF THE OS-CALCIS FOR PAINFUL HEEL WITH CALCANEAN SPUR

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Accepted 26 ii 73

Painful heel associated with bony spur of the os-calcis is a distressing condition The patient feels severe pain on the inferior aspect of the heel, particularly in the morning and after a period of rest The pain usually improves with activity and recurs after prolonged standing and walking The condition is slowly progressive to the extent that the patient may become disabled

Up till now the cause of the condition has been obscure, however, numerous factors have been claimed to produce painful heel with a bony spur (Table 1) These cases had been treated by various conservative methods (Table 1), or by a combination of one or more of them Though successful in some cases, this treatment proved useless *in the majority of them For such cases various surgical procedures* have been described (Table 2)

The variability of these surgical procedures denotes that none is entirely satisfactory Moreover, the small number of the reported cases and the short period of post-operative follow up can be easily criticized, so that the results reported are unreliable

In our orthopaedic department, since 1966, 68 patients presented with inferior heel pain, associated with bony spur of the os-calcis, 26 of *them were bilateral (52 heels) These cases were seen,* investigated, and treated conservatively and finally assessed in 1973 for the sake of this paper

The methods of treatment adopted were (1) non specific anti inflammatory drugs using the phenylbutazone group of drugs, (2) leather heel pad with a hollow corresponding to the tender area, (3) local injection of 25 mg crystalline suspension of hydrocortisone acetate and 2 ml of 2 per cent novocaine

Table 1 Causes and treatment of bony spur of the os-calcis

Authors	Causes	Number of cases	Treatment
Swett & Stoll (1916)	Hereditary syphilis	9	Specific treatment
Liberson (1932)	Gonorrheal	31	Deep X ray therapy
Blokhin & Vinogradova (1937)	Functional overuse	33	Conservative treatment
Steindler & Smith (1938)	Functional overuse	49	Conservative treatment
Davis & Blair (1950)	Strumpell Marie disease	15	Conservative treatment
Rose (1955)	Chronic strain of the plantar fascia	17	Insole in the shoe
Kivel (1955)	Myositis	1	Insole & local cortisone with novocaine
Blocky (1956)	No definitive cause	19	Local cortisone
Eggers (1957)	Fasciitis & bursitis		Egger's heel pad
Thurner & Boni (1957)	Degenerative	37	Conservative treatment

Table 2 The surgical treatment of bony spur of the os-calcis

Operations	Authors	Cases	Follow up	Results	
				Good	Bad
Excision of the spur	Baer (1906)	5	11 months	5	–
	Wachter & Sonnenschein (1915)	4	–	4	–
	Von Lackun & Palamoque (1930)	16	1–3 years	12	4
	Steindler & Smith (1938)	16	20 months	7	9
	DuVries (1957)	37	2 cases For 2 years	37	–
Plantar fasciotomy	Spitzy (1937)	9	10 months	9	–
Rotational osteotomy	Steindler & Smith (1938)	6	11 months	6	2
Countersinking osteotomy	Michele & Krueger (1950)	2	1 year	2	–

RESULTS OF CONSERVATIVE TREATMENT

Excellent results

We obtained dramatic relief of symptoms in 16 cases (23 5 per cent) It was noticed that the duration of the pain in these cases was from 15–30 days After a period of 6–9 months recurrence of pain occurred in 11 of these cases and they were treated surgically

Our last follow-up of 1973 proved that the other 5 cases still have permanent relief since their conservative treatment in 1966 It is evident here that the very short duration of symptoms before treatment was instrumental in this relief

Moderate results

We got slight immediate relief of pain in 39 cases (57 5 per cent) in which the duration of pain before treatment was from one to six months After a period of 3–6 months recurrence of pain took place in 19 cases which therefore were subjected to operative treatment In the last follow-up of 1973 for the remaining 20 cases, recurrence of the same pain occurred as before in 5 cases, 3 could not be traced, and the remaining 12 cases still have moderate relief and are satisfied though they are not completely free

Bad results

Thirteen cases in which the duration of pain before treatment was more than 6 months did not respond to our conservative treatment and were therefore treated surgically from the start

These resistant cases (13) together with the recurrent cases (11+19) and a group of 17 cases treated conservatively elsewhere without response were treated by drilling of the os-calcis

MATERIAL AND METHODS

In the Department of Orthopaedic Surgery University of Alexandria the simple operation of drilling of the os calcis has been used in the last 6 years in the treatment of resistant and recurrent cases of painful heel with a bony spur i e the chronic cases which did not respond to any of the conservative methods of treatment

Sixty cases of resistant and recurrent painful calcaneal spur were the subject of our study, 8 of them were bilateral There were 42 males and 18 females The age of the patients ranged between 20 and 80 years 34 were above 40 8 between 20 and 30 and 18 between 30 and 40 years

It was noticed that females were obese, and that all males were heavy workers and had to stand for long durations

The patients complained of pain and tenderness over the inferior aspect of the heel 28 could not put their heels at all on the floor 32 felt pricking pain in the heel that interfered with their usual activities and during rest deep aching pain was felt after walking for a short distance All stated that the inferior heel pain was worse in the morning when getting out of the bed or after a period of rest The pain improved on walking but returned on prolonged standing

The duration of symptoms was 8–11 months in 10 cases 1–3 years in 34 cases and 3 5 years in 16 cases

Associated conditions

Eight cases had high arched foot and 7 had flat foot 4 cases had hyperuricaemia Osteoarthritis of the knees was present in 30 cases Diabetes mellitus was found in 4 cases and hypertension in 6 other cases

The right heel was affected in 30 the left in 22, and both heels in 8 patients

All these patients were given the chance of conservative treatment by a combination of different measures including repeated local injection of hydrocortisone acetate crystalline suspension (25 mg) mixed with novocaine 2% solution No improvement was obtained in 13 cases and pain recurred after a short duration of incomplete improvement in the other 30 cases To these was added a third group of 17 cases which were treated conservatively in other hospitals without response, all these were considered resistant chronic cases of painful heel with calcaneal spur

Operative technique

Under general or local anaesthesia a small curved incision about 3 cm was made over the lateral surface of the heel extending below the lateral malleolus It was deepened down to the bone securing the sural nerve The periosteum was stripped off the bone to the peroneal tendons anteriorly and to the small muscles of the foot inferiorly Bone levers were inserted between the bone and the tendo calcaneus and between the os calcis and the muscles of the sole Multiple small drill holes were than made in the calcaneus traversing the bone from the lateral to the medial cortex From 7 10 holes were usually made The wound was closed and a soft bandage applied

Post operative management

The patient is instructed to walk on the third post-operative day, and the stitches are removed on the tenth day

RESULTS

Sixty-eight operations were performed on 60 patients (8 bilateral) with resistant heel pain associated with bony spur of the os calcis In 62 operations there was immediate and dramatic relief of the heel pain and local tenderness on the second post-operative day The patients

RESULTS OF CONSERVATIVE TREATMENT

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Sixty cases of resistant and recurrent painful calcaneal spur were the subject of our study, 8 of them were bilateral There were 42 males and 18 females The age of the patients ranged between *20* and *80* years *34* were above *40 8* between *20* and 30 and 18 between 30 and 40 years

SUMMARY

Sixty cases (68 heels) of painful heels resistant to conservative treatment and accompanied with calcanean spur were treated by a new surgical method in which the calcaneus was perforated by multiple drill holes The relief of pain was immediate in 62 heels After a follow-up of 2 to 6 years no recurrence was noticed

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returned to their usual work two weeks after the operation No pain recurred during the period of follow up of two to six years In two cases there was mild superficial skin infection which delayed the improvement for about one month Four failures were encountered, the first case was gouty (blood uric acid was 6 8 mg per cent) The second case got bone infection, and the last two cases had rigid flat foot (Table 3)

Table 3 Results of the operation

No of operations	Excellent	Good	Bad
68	62	2	4

However, when this operation was applied to fairly recent cases, as was done by some of our colleagues, the results were not so favourable

Advantages of the operation

1 It gives constant immediate and so far permanent excellent results in the resistant chronic cases not responding to conservative treatment
2 It is a very simple surgical procedure which can be done under local anaesthesia
3 It neither disturbs the normal anatomy of the region nor the biomechanics of the heel
4 The post operative care is very simple and short the patient is hospitalized for not more than 10 days, and resumes his usual activities two weeks after the operation

CONCLUSION

1 In our opinion, drilling of the os calcis is an ideal operation for the treatment of chronic resistant cases of painful heel with a bony spur, but when applied to fairly recent cases or to cases with a definite etiological factor the results are not so favourable
2 The relief of pain in the way described in this paper for chronic resistant cases by simple drilling of the os calcis suggests that this operation may induce a sort of decongestion or decompression of the calcaneus, however this hyposthesis is a subject of further studies in our section



Figure 1 Extensive calcification together with spindle shaped cells

the foot a well circumscribed nodule was approached and was found adherent to the medial border of the plantar fascia The nodule was carefully excised and the wound sutured The post-operative course was uneventful

The specimen was white grey firm and measured 1 5 cm at its greatest diameter

Two stained slides with tissue material from the specimen were sent to the Department of Pathology of the Royal Postgraduate Medical School, London

The report, by Prof Harrison, reads " Series of small roughly rounded cellular areas separated by looser and less cellular tissue The lesion has surrounded some strands of original collagen fibre. The cellular part consists of haphazardly-arranged spindle-shaped cells Mitotic figures are present but not frequent Inflammatory cells were not seen Parts of the tumour are quite extensively calcified (Figure 1).

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JUVENILE APONEUROTIC FIBROMA

Report of a Case

P K VATOPOULOS, E E GAROFALAKIS & B T PAPATHANASSIOU

Accepted 7 x 73

This rare condition was first described by Keasbey in 1953 The author noted its predilection for children, its tendency to recur after excision and the lack of metastases The lesion is characterized on a microscopic level by proliferation of connective tissue cells, with parts of it showing calcification and a cartilaginous differentiation of a varying degree

Lichtenstein & Goldman (1964) regarded this lesion as being the cartilage analogue of fibromatosis Harrison in 1971 referred to the disease as being rare, a fact illustrated by a review of the literature which revealed only 15 similar cases

This paper deals with another case of "juvenile aponeurotic fibroma", the first to be described in Greece

CASE REPORT

In 1967 a fourteen year old boy started complaining of pain in the middle of the medial aspect of the left foot The pain was elicited by local pressure and was intense enough to hinder walking

Three years later and elsewhere he underwent a biopsy the report of which could not be traced Nevertheless the pain and disability reappeared after a short time and the patient was admitted to our Department in July 1971

On examination he was a well developed healthy adolescent who walked with a limp Movements of the left foot were normal and painless Muscle power was normal Sensation of the foot was normal A 6 cm long surgical scar was noted in the middle of the medial aspect of the left foot On palpation a very sensitive area measuring 2 cm in length was discovered in the middle of the scar There existed no physical findings of infection and the lymph nodes of the extremity were not enlarged Blood chemistry was normal and the roentgenographic examination of the foot was negative

Exploration of the lesion was decided upon General anaesthesia and a tourniquet were used Through a 6 cm longitudinal incision centred over the sensitive area of

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POST-OPERATIVE WOUND INFECTIONS IN CLEAN ORTHOPAEDIC SURGERY

Review of a 5-year material

LARS LIDGREN & LARS LINDBERG

Accepted 16 viii 73

In the analysis of postoperative infections it is important to compare not only the overall infection rate but also the incidence of infections after each type of operation Kocher (1893) reported a postoperative wound infection rate of 2 3 per cent This figure is remarkably similar to the postoperative wound infection rates today However, this similarity is misleading because it does not take into account the different types of surgical patients involved, together with the more extensive surgical procedures and the introduction of new osteosynthetic materials today The development of new antibiotics continually changes the bacterial spectra and also the nature of infection Therefore, in order for it to be possible to prevent and to treat these infections they must be thoroughly followed and analysed

This paper reporting postoperative infections is one of a series (Lidgren & Lindberg 1972 a, b, 1973, Lidgren 1973 a, b) based on a 5 year material of orthopaedic infections encountered in a population of a quarter of a million

MATERIAL AND METHODS

During the 5 year period 1963 through 1967 all patients with orthopaedic infections at the Department of Orthopaedic Surgery, Malmö General Hospital were subjected to analysis This 1,500 bed hospital is the only hospital for somatic diseases for the population of Malmö (241 778 inhabitants Dec 31 1963 and 254,338 inhabitants Dec 31 1967) and is therefore suitable for an epidemiologic study (Lidgren & Lindberg 1972 a) The Department of Orthopaedic Surgery has 150 beds and is responsible for both classic orthopaedics and fracture surgery

In my opinion this is a calcifying juvenile aponeurotic fibroma These lesions may recur after excision but they do not metastasise"

No other measures were taken after diagnosis was established and the patient was followed up in the Clinic At the time of his last examination, sixteen months postoperatively, the patient had no complaints, walked normally and there were no physical signs of recurrence

COMMENT

The aetiology of this condition remains unknown

The review of the literature by Rios-Dalenz et al (1965), revealed that both sexes are equally affected and that the lesion shows a predilection for the hand

It usually causes very few symptoms, although in our case local pain was strong enough to cause limping

It could be postulated that incomplete excision of the lesion is responsible for the local recurrences

SUMMARY

A case of juvenile aponeurotic fibroma of the foot is presented Surgical excision was performed Follow-up of the patient revealed no recurrence

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The frequency of postoperative infections increased significantly with age ($\chi^2 = 69$, df $= 4$) ($P < 0.001$) from less than 0 5 per cent below age 25 to close to 9 per cent above age 75 However, within the group of 219 cases of trochanteric femoral fracture operated with nail and plate with 32 (15 per cent) postoperative infections, no increase in the infection rate with age was found only 40 patients were below age 65 The age corrected incidence of infection was the same in males and females ($\chi^2 = 5\ 3\ 4$, $P > 0\ 05$)

Table 1 Age and sex distribution of patients with postoperative infections in Malmo 1965–1967

Age	Males		Females		Total			
	Number of opera tions	Number infec tions	Number of opera tions	Number infec tions	Number of opera tions	Number infec tions	Major infec tions	% infec tions
0–14	122	0	66	0	188	0	0	0
15–24	250	2	95	1	345	3	1	0 9
25–44	552	10	250	6	802	16	7	2 0
45–64	679	24	630	13	1309	37	24	2 8
65–74	158	12	323	19	481	31	15	6 4
75 and older	113	7	379	37	492	44	28	8 9
Total	1874	55	1743	76	3617	131	75	3 6

The difference in figures between the tables is because of data technical faults which have not been possible to correct

In Table 2 the distribution of postoperative infections among anatomic locations during 1965 through 1967 in our investigation is compared with three earlier reports The hip region ($P < 0\ 001$) was found to be a high risk location the spine ($P < 0\ 05$) and the knee joint ($P < 0\ 01$) were low risk locations The correlation of postoperative infection with different types of operation showed that the use of osteosynthetic material ($P < 0\ 001$) carried a higher risk (Table 3) Of the 72 arthroplasties performed, 62 were Moore prostheses with 7 infections (5 major) The remaining 10 were Smith Petersen arthroplasties with 2 minor infections

Bacterial cultures were available in 160 of the 185 cases, in seven cases no culture was performed In 107 (67 per cent) Staph aureus was the only pathogenic bacterium and in 23 others it was associated

During the entire 5 year period of investigation 5,724 clean operations were performed on inpatients The postoperative infections were recorded as major or minor (Lidgren & Lindberg 1972 a) Starting in 1965 data on all patients were stored in a computer During the 3 year period 1965-1967, 3 617 clean operations were performed All patients during that latter period could therefore be compared as regards sex, age, diagnosis, anatomic location, type of operation and duration of stay in hospital

Material from infected wounds or joints was obtained for culture In those cases where bacterial cultures were negative or not performed the postoperative infection was diagnosed on the basis of local inflammation, the clinical course, elevated E.S R, positive serological findings, prompt response to antibiotics etc The courses of the infections were analysed and notes were made as to whether the bacteria had been susceptible to the antibiotic given initially

Toward the end of 1972 all of the hospital records were studied to find out whether the infections had had any demonstrable effect on the late results of the operations Patients with bacterial arthritis (Lidgren & Lindberg 1973) and chronic osteitis (Lidgren & Lindberg, to be published) were reviewed during 1971-1972 clinically and radiographically

The results of the operations were regarded as having been spoiled by the infection if,

1 an endoprosthesis had to be removed, 2 osteosynthetic material had to be removed before a fracture or osteotomy had healed, 3 chronic osteitis had developed, 4 bacterial arthritis had resulted in destruction of a joint, 5 deformity had occurred as a late consequence of infection and/or because of disturbed growth 6 function was impaired as a direct consequence of the infection

Statistical methods

The statistical analysis was performed in co operation with Peter Vorwerk of the Department of Mathematic Statistics at the University of Lund The methods used were chi squared tests When comparing anatomic locations each of eleven subset groups were compared with the remaining material by single chi square tests and high risk and low risk groups respectively, were determined The tests were made simultaneously by multiplying the individual significance levels by eleven When comparing different types of operations high and low risk groups respectively were determined by simultaneous tests for seven groups of operations

RESULTS

In 1963 through 1967 a total of 5,724 clean operations were performed on inpatients Of these, 185 (3 2 per cent) became infected and in 107 (1 9 per cent) the infection was classified as major During the last three years of this period 3,617 clean operations were performed and infection occurred in 131 (3 6 per cent) including 75 (2 1 per cent) in whom the infections were classified as major The incidence of infections in relation to sex and age is shown in Table I

of these were in the hip region Eight were cervical (all subjected to open reposition) and 11 trochanteric femoral fractures In seven cases the condition of the patient was so severe before the operation, however, that the effect, if any, of the infection could not be assessed with certainty In 130 cases the infection had not affected the late result In only one case was the infection the direct cause of death

Table 3 Distribution of postoperative infections in different types of operations, Malmö 1965–1967

	Number of operations	With postoperative infections	Major infections
Amputations	155	5	1
Arthrodesis with osteosynthetic material	46	1	1
Arthrodesis without osteosynthetic material	38	1	1
Arthroplasties with endoprosthesis	72	9	5
Arthrotomy	665	18	6
Open reduction of fracture with osteosynthetic material	1143	61	43
Open reduction of fracture without osteosynthetic material	42	2	2
Osteotomy with osteosynthetic material	54	8	4
Osteotomy without osteosynthetic material	91	0	0
Removal of osteosynthetic material	178	4	3
Spine operations including disc herniation	487	6	0
Miscellaneous	665	17	8
Total	3787	131	75

DISCUSSION

The widening of the indications for operations to include patients classified as poor surgical risks and the introduction of new osteosynthetic material is apt to give a false impression that the frequency of postoperative infections is unchanged In the beginning of the era of so called aseptic surgery, poor risk patients were operated upon only exceptionally because of the risks involved with anaesthesia and inadequate knowledge of the fluid electrolyte balance, heart and renal function We can now carry almost all poor surgical risks through an operation but we still have difficulties in keeping the risk of infection down to a reasonable level

with other bacteria In 84 (65 per cent) of these 130 cases the bacteria were found to be resistant to penicillin already at the first culture Twelve patients received no antibiotics because the infection had healed before the bacteriologists report had been received In 57 (32 per cent) of the remaining 148 cases the pathogenic bacterium was not sensitive to the primary antibiotic given A closer analysis of the bacteriology will be published separately (Ericson & Lidgren, to be published)

Table 2 Anatomical distribution of operations and infections

Region	Tachdjian & Compere 1952–1957		Räf 1959–1962		Stevens 1960		Own investigation 1965–1967		
	Number of operations	Number of infections	Number of operations	Number of infections	Number of operations	Number of infections	Number of operations	Number of infections	Major infections
Spine	566	7	288	15	173	8	510	6	0
Hip	401	14	528	31	321	14	1010	76	18
Thigh	160	1	241	11	68	4	123	6	4
Knee	316	3			181	4	667	8	2
Leg	178	4	183	5	63	4	278	7	4
Ankle	120	2			67	1	292	3	2
Foot	551	7	481	13	131	7	163	6	4
Neck	48	0	–	–	8	0	–	–	–
Shoulder clac, scapula	108	2			28	1	62	2	1
Arm	91	0			24	1	31	2	2
Elbow	118	1			54	2	50	1	1
Forearm	126	1	124	0	72	6	110	1	1
Wrist	55	1			30	0	2	0	0
Hand	161	1			59	4			
Thorax	–	–	–	–	2	0	–	–	–
Pelvis	–	–	–	–	7	0	11	1	1
Miscellaneous	–	–	80	0	–	–	518	12	5

In 48 cases (26 per cent of all infections), the infection was considered to have spoiled the results of the operation, and in 32 of these osteosynthetic material had been used In 42 of the 48 cases with spoiled results the location was in the lower extremities Twenty-four

of these were in the hip region Eight were cervical (all subjected to open reposition) and 11 trochanteric femoral fractures In seven cases the condition of the patient was so severe before the operation, however, that the effect, if any, of the infection could not be assessed with certainty In 130 cases the infection had not affected the late result In only one case was the infection the direct cause of death

Table 3 Distribution of postoperative infections in different types of operations Malmö 1965–1967

	Number of operations	With post operative infections	Major infections
Amputations	155	5	1
Arthrodesis with osteosynthetic material	46	1	1
Arthrodesis without osteosynthetic material	38	1	1
Arthroplasties with endoprosthesis	72	9	5
Arthrotomy	665	16	6
Open reduction of fracture with osteosynthetic material	1143	61	43
Open reduction of fracture without osteosynthetic material	42	3	3
Osteotomy with osteosynthetic material	64	8	4
Osteotomy without osteosynthetic material	91	0	0
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Infection rate

The overall postoperative wound infection rate in clean orthopaedic surgery varies between 0 7 per cent (Jeljaszewicz & Bobr 1968) and 8 8 per cent (O'Riordan et al 1972) In most investigations it is between 2–5 per cent (Henderson & Kornblum 1961, Schonholtz et al 1962, Maguire 1964, Raf 1964, Stevens 1964, Towers 1965, Dencker 1965, Derian & Green 1966, Annals of Surgery 1964, Jeffrey & Sklaroff 1968 Zifko & Vlasich 1968, Bruun 1970) About half of the infections have been recorded as major (Tachdjian & Compere 1957, Maguire 1964, Raf 1964, Derian & Green 1966, O'Riordan et al 1972) In our material the overall infection rate was 3 2 per cent and in 1 9 per cent the infection was classified as major This does not differ from what has been reported by other authors

Anatomic location

In three earlier series (Table 2) the frequency of postoperative infection was reported with respect to anatomic locations Tachdjian & Compere (1957) found a significantly higher infection rate after operation in the hip region and Raf (1965) a significantly higher frequency after operation in the spine, hip and thigh region Stevens (1964) compared different regions but found no difference In our material the frequency of infection was particularly high in the hip region and low in the spine

Type of operation

Stevens (1964) found a clear increase in the frequency of infection in association with the insertion of osteosynthetic material and doubling of the frequency when two or more operations were performed at the same time The use of osteosynthetic material was also associated in our material with a significantly increased frequency of infection Insertion of osteosynthetic material in the often more complicated cases with a foreign body effect may possibly explain the increase of infections in these patients However, this does not imply that there would have been a lower infection rate if osteosynthetic material had not been used

Late result of the infection

In 26 per cent of our cases the infection spoiled the operation In two-thirds of these osteosynthetic material was used In one previous

report (Raf 1964) the final result of the postoperative infection in orthopaedic surgery has been analysed, in 37 per cent of his cases with postoperative infection the result was spoiled In our material only one patient died as a direct cause of the postoperative infection

A large number of factors believed to increase the frequency of postoperative infection have been analysed by several investigators In a few investigations attempts have been made statistically to correct for possible interfering background factors An increase of postoperative infections has thus been shown with age, duration of preoperative hospitalisation, co-existing infection elsewhere (e g of the nose, skin, urinary tract), type of preoperative washing, duration of operation, length of incision, drainage, the number of persons present in the operating theatre, the time of the day the operations are performed (Lancet 1960 Hendersen & Kornblum 1961, Annals of Surgery 1964, Raf 1964 Stevens 1964, Gillquist 1967, Jeljaszewicz & Bobr 1968, Bruun 1970) Annals of Surgery (1964) reported a significant increase of postoperative infections in patients with malnutrition, overweight, diabetes and patients undergoing steroid treatment while Stevens (1964) and Bruun (1970) found no increase for these We have previously reported that the incidence of postoperative infections in patients with diabetes (Lidgren 1973 a) or rheumatoid arthritis (Lidgren 1973 b) was not increased

In this material the following parameters have been analysed, age, anatomical locations and type of operation Within a group of trochanteric femoral fractures no increase in the incidence of postoperative infections with increasing age could be found It is clear, however, that operations in the hip region together with insertion of osteosynthetic material not only significantly increase the incidence of postoperative infection but also account for no less than 60 per cent of all postoperative infections and half of the spoiled results after operation Strictly aseptic routine in major hip operations seems highly necessary In these operations special procedures such as steril enclosure (Charnley 1972) or even limited antibiotic prophylactic treatment (Ericson et al 1973 Lidgren & Lindberg 1973 b) are clearly indicated

SUMMARY

A prospective study of 185 (3 2 per cent) postoperative infections in 5 724 clean orthopaedic operations during a 5 year period is reported

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SUMMARY

A prospective study of 185 (3.2 per cent) postoperative infections in 5 724 clean orthopaedic operations during a 5 year period is reported

107 of the infections were classified as major Analysis of the anatomic location and the type of operation showed that the incidence of infection was highest for operations in hip regions Staphylococcus aureus was the only pathogenic bacteria in 107 cases (67 per cent) In 57 (32 per cent) the pathogenic bacteria was not susceptible to the primary antibiotic given Only one patient died of the infection but the late result of the operation was spoiled by infection in one-fourth of the cases *Various factors affecting the frequency of postoperative infections are discussed*

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Table 1 Measuring sites and their precision as obtained from replicate measurements in 19 male office employees

	Precision*, %
Radius + ulna distal	3 5
Radius + ulna shaft	9 5
Humerus head	2 1
Third lumbar vertebra	10 (2 8§)
Femur, neck	2 0
Femur shaft	2 2
Calcaneus	3 9

* Precision Standard deviation, expressed as a percentage of the mean bone mineral content at the respective sites

§ Manual setting of the zero base line

By stratified random selection from the Stockholm population a control group of 31 men was formed The study was incomplete there being 7 absentees (Age distribution of measured controls 45–49, (n = 10) and 55–59 (n = 14), mean 52 8)

The cross-country runners and the controls were of similar body size, mean body height 176 and 176 cm and mean body weight 73 and 75 kg respectively

The short term physical activity group consisted of 19 male office employees aged 25–52 (two others were excluded before the completion of the study because they withdrew from the training program) The group trained for three months 10 persons walked 3 kilometers five times a week and 9 persons ran 5 kilometers three times a week The maximum oxygen capacity was determined before and after the training period

RESULTS

The bone mineral content was, on average, greater for the cross country runners than for the control group (Table 2, Figure 1) The difference between the groups, expressed as a percentage of the values for the controls was greater for the sites containing trabecular bone—for example the calcaneus, head of the humerus and distal radius and ulna The difference between the groups at these sites was investigated with an F test (Discriminant analysis BMD 07M, Dixon 1967), and the difference was found significant ($P < 0.01$) The largest F-value, however was obtained for the shaft of the femur, this is due to a very small biological variation for this site (Dalen & Jacobson, in press)

The short term physical activity group did not show any significant increase ($P > 0.05$) in the amount of bone mineral at the end of the training period (Table 3) A mean increase of 0 5 per cent in the aver-

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BONE MINERAL CONTENT AND PHYSICAL ACTIVITY

NILS DALÉN & KARL ERIK OLSSON

Accepted 2 viii 73

The treatment of osteoporosis is an unsolved medical problem This study was designed to examine whether increased physical activity can raise the amount of bone mineral in the skeleton, or, at least, retard the reduction with age (cf Smith 1971, Nilsson & Westlin 1971) The bone mineral content of chosen parts of the skeleton was measured after long-term physical activity and before and after a relatively short period of increased physical activity

METHODS AND MATERIAL

The bone mineral content was determined by x ray spectrophotometry (Gustafsson et al in press) This method is based on attenuation measurements employing a scintillation detector The mineral content at a particular site is determined by scanning with a well collimated slit shaped x ray beam The attenuation by the soft tissues is compensated for by using two radiation energies

By the x ray spectrophotometric method the amount of bone mineral in the radiation beam is measured per unit area (mg/cm²) By scanning over a site the bone mineral content is obtained per unit length of the bone (mg/cm) In the present study the bone mineral content is thus obtained in mg/cm

The measuring sites were selected so as to obtain representative values for trabecular and cortical bone body weight loaded and unloaded bone and axial and appendicular bone When possible sites used by other investigators were chosen to enable a comparison to be made The sites and their precision are given in Table 1 (cf Dalen & Jacobson in press)

The long term physical activity group consisted of 15 cross country runners who had been practising the sport for at least 25 years This branch of athletics was considered to be particularly suitable for the purpose of the study because it is often pursued to an advanced age The runners aged 50 59 (mean 54 6) were chosen by stratified random selection from all participants in the 1970 Stockholm district championship Throughout the study attendance was 100 per cent

This work was supported by the Swedish Medical Research Council (project no 23X 2580)

Table 3 The difference in bone mineral content before and after the physical training period

	Mean difference*, %
Radius + ulna, distal	+1 66
Radius + ulna, shaft	+0 08
Humerus head	—1.51
Third lumbar vertebra	—0 47
Femur neck	+0 75
Femur, shaft	—1 72
Calcaneus	—0 26

* Expressed as a percentage of the mean bone mineral content at the respective sites

sites was not significant ($P > 0\ 05$), (Analysis of variance, BMD 08V, Dixon 1967) The correlation between the observed change in bone mineral and the increase in the maximum oxygen capacity was not significant ($P > 0\ 05$), (Correlation, BMD 03D, Dixon 1967)

DISCUSSION

The values for the bone mineral content in Table 2 have not been corrected for age and body size, the cross-country runners and the control group being very similar in these respects (mean age 55 and 53 years, mean body height 176 and 176 centimeters, and mean body weight 73 and 75 kilograms, respectively) If such corrections were made the difference in bone mineral content between the two groups is even greater than that reported

The high bone mineral content of the skeleton of cross-country runners is in accordance with the results reported by earlier investigators regarding athletes (Nilsson & Westlin 1971) It is remarkable, however, that the mean bone mineral content is 20 per cent higher for the runners than the controls not only for the calcaneus but also for the head of the humerus and the distal radius and ulna Moreover, the values for the clinically relevant measuring sites in the axial skeleton, namely, the neck of the femur and the third lumbar vertebra, were only 8 and 9 per cent, respectively, higher than those for the controls To judge from the result of this study, physical training would seem to have little effect on the amount of bone mineral in the axial loaded skeleton, but there is some evidence that it is of importance for the appendicular skeleton This is in agreement with the results obtained by Oeser & Krokowski (1963)

Table 2 Bone mineral content for cross country runners and control subjects The deviation for the runners is expressed as a percentage of the mean values for the controls

Measuring site	Mean bone mineral content: Cross country runners (mg/cm)	Mean bone mineral content: Controls (mg/cm)	Deviation %	$F_{1,37}$*
Radius + ulna, distal	2029	1712	+19	12
Radius + ulna shaft	2455	2327	+ 6	2 8
Humerus, head	2886	2425	+19	14
Third lumbar vertebra	5404	4975	+ 9	1.2
Femur, neck	3764	3496	+ 8	1 9
Femur, shaft	6157	5738	+13	18
Calcaneus	3487	2890	+21	17

* A value of F greater than 7 3 is significant, $P < 0\ 01$, n = 39

age bone mineral content of the individuals would have been significant (Student's t-test, $P < 0\ 05$), but in fact it was – 0 21 per cent (standard error of mean 0 22 per cent)

During the training period there was an increase in the maximum oxygen capacity of all the participants, and the mean increase for the group was 11 per cent (standard error of mean 1 2 per cent)

The difference in the change of bone mineral content between those trained by walking and those trained by running, the difference between individual subjects, and the difference between the 7 measuring

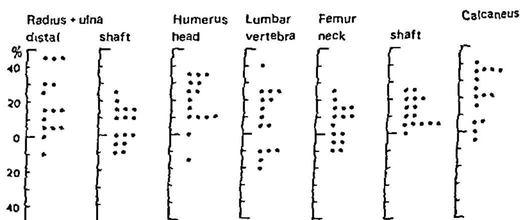


Figure 1 Bone mineral values for cross country runners The values are expressed as the per cent deviation from a control group matched for age sex and body size

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INVESTIGATION OF THE CELLULAR RESPONSE TO FRACTURE ASSESSED BY AUTORADIOGRAPHY OF THE PERIOSTEUM

NIELS HYLDEBRANDT, WILLIAM DAMHOLT & ERIK L. NORDENTOFT

Accepted 15 viii 73

The uptake of tritiated thymidine into synthesized DNA of cells in mitosis has been widely used for studying proliferating cells in many tissues. Cells which have incorporated labelled thymidine into their nuclei may be located in serial sections by autoradiographic methods (McLean & Urist 1961, Owens 1963, Tonna & Cronkite 1961).

By this means it is possible also to locate areas with proliferative activity, observe the migration of cells from one site to another, or estimate stages in the degree of differentiation. The periosteal surface is considered a relatively simple system for studying bone growth. In the resting bone the cells are situated in a fairly well defined layer and exhibit long, slender, spindle shaped, dark nuclei. The periosteal layer is discernible with fair certainty from the adjacent muscle layer, and it is delimited by the cortical membrane from the medullary, proliferating cells of the bone.

In the present study we employed the autoradiographic method for assessing the rate and spread of the proliferation induced in the periosteum of long bones after fracture. The object was to measure the increment of cells in the immediate vicinity of the fracture, along the length of the fractured bone and on the symmetrical, non fractured bone, and also to determine the time of maximum cell proliferation after the fracture.

MATERIAL AND METHOD

The experimental animals were 44 five week-old NMRI mice. Under ether anaesthesia a uniform bending fracture was induced by digital pressure on the mid shaft of

In spite of an 11 per cent increase in the maximum oxygen capacity during the three-month training period, no increase in the bone mineral content was observed. It would thus seem impossible to obtain a rapid increase in the amount of bone mineral in the skeleton of healthy normal male subjects by means of physical training. No conclusions can be drawn from these results regarding the effect of physical training under pathological conditions.

SUMMARY

The bone mineral content at seven measured sites was, on average, greater for 15 cross-country runners than for a control group The difference between the groups was about 20 per cent for the trabecular, appendicular measuring sites (distal radius and ulna and calcaneus), but less than 10 per cent for the axial sites (lumbar vertebra and the neck of the femur).

A three-month period of increased physical activity in 19 male office employees did not result in an increased bone mineral content in spite of an 11 per cent increase in maximum oxygen capacity

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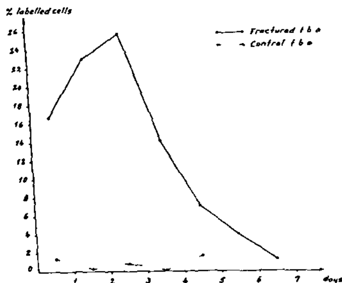


Figure 2 Labelling index in the periosteum from a fractured and non fractured tibia Zero time represents the time of the fracture

ne tibia The contralateral tibia was used as control, supplemented by preparations fr m two non traumatized mice

One hour l efore the specimens were prepared (after the mice had been killed b an over d se of ether) tritium labelled thymidine was injected subcutaneously in a d sage of 1 mC/g During the first 3 days specimens were prepared every 4 h urs from 2 mice During the subsequent 16 days 2 mice were used each day

Immediately after sacrifice the bones were dissected free under an operation lens, fixed decalcified embedded in paraffin and cut into 5 μ sections For the auto radiography we used a Kodak K 5 emulsion The specimens were exposed for 12 days in dry air at 4° C. After developing and fixation they were stained with haematoxylin eosin

Since an additional purpose of this study was to assess the validity of the method as an indicator analysis in studying the union of fractures the specimens were c ded and examined microscoplally by two persons independently of each ther A third person adjusted the specimens to a periosteal area near the fracture an l a peri steal area away from the fracture but on the fractured bone and a l aphyseal as well as metaphyseal area on the control tibia

A t tal of 2 4 counts were made each representing one field of the microscope at a magnificati n of $\times$ 1000 No regard was paid to the differentiation of the peri steal cells the counts merely including labelled and non labelled cells in the peri steal layer

Figure 1 a Autoradiograph of a fractured tibia from a 5 week old mouse (× 250)

Figure 1 b Autoradiograph of the periosteum from a fractured tibia (× 1000)

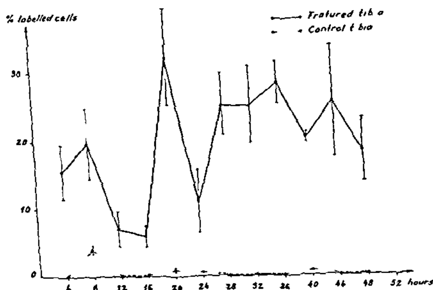


Figure 4 Labelling index showing the standard deviation on the individual counts during the first 48 hours after the fracture

labelled cells on the fractured bone—near the fracture as well as away from the fracture—ran a parallel course graphically

On the other hand, there was a significant difference in the labelling percentage between the two areas on the 1st and 2nd day (T value 2 753 $P < 0.02$ T value 2 397 $P < 0.05$), whereas the difference from the 3rd day onwards was not significant

Figure 4 shows the percentage of labelled cells every four hours on the fractured bone and control bone, stating the standard deviation on the means From Table 1 as well as from Figure 4 it is apparent that the standard deviation on the individual mean values representing one set of specimens is high (coefficient of variation 14–23 per cent) Moreover there seems to be a marked variation in the number of labelled cells from one set of specimens to another On the other hand there is satisfactory agreement between the two independent countings, the mean difference being 0 08 plus 1 3 with a standard deviation of 4 5 (cf Table 1)

CONCLUSION AND DISCUSSION

In the present study we found autoradiographic methods to be well-suited to indicator analysis for assessing fracture-induced cellular

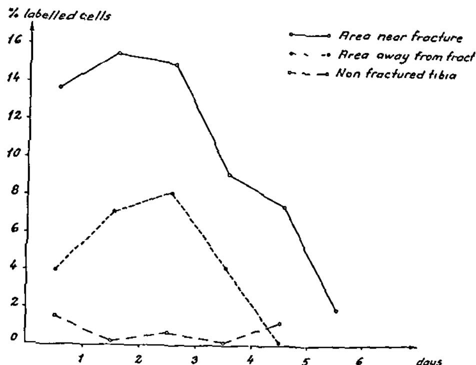


Figure 3 Labelling index in the periosteum from an area near the fracture an area away from the fracture, and from a non fractured tibia Zero time represents the time of the fracture

RESULTS

Figure 2 is a graphic presentation of the number of labelled cells in the periosteum on the fractured tibia and the control tibia The values are expressed as per cent labelled, out of the total number of cells counted The values per 24 hours represent the mean values of counts made during the 24 hours

There was a significant difference between the number of labelled cells on the fractured bone and on the control bone during the first 3 days (1st day T value 3 323 $P < 0\ 005$, 2nd day T value 7 530 $P < 0\ 001$, 3rd day T value 3 315 $P < 0\ 02$) The percentage of labelled cells on the fractured bone was 16 26, with a distinct peak between the first and the second day On the control bone the number of labelled cells ranged from 0 2 per cent After the 7th day the number of labelled cells was the same on both sides

In Figure 3 the counting results on the fractured tibia are specified for the area near the fracture and the area away from the fracture and compared with the control bone Here too the values represent the mean of counts during 24 hours It is apparent that the number of

SUMMARY

With the aid of autoradiography fracture induced cellular proliferation in the tibial periosteum was assessed in 5 week old albino mice during the period one hour to 17 days after the trauma

The proliferative response set in 8 16 hours after the fracture reaching a maximum in 20 to 28 hours The response was most marked at the site of the fracture but was demonstrable also on the tibial diaphysis and on the contralateral, non fractured tibia

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Table 1

Hours after fracture	Number of labelled cells x examin	y-examin	differ x-y
4	26	27	—1
8	20	20	0
12	12	7	+5
16	6	7	—1
20	40	43	—3
24	21	13	+8
28	84	93	—9
32	47	43	+4
36	46	45	+1
40	29	34	—5
44	12	10	+2
48	18	20	—2
Mean	30	31	0 08
S D			4 5
S E D			1 3
Paired 'T" = 0 063 ~ P = 0 96 (N = 12)			

proliferation in the periosteum By the same method Tonna & Cronkite (1961) found cellular proliferation 8–16 hours after fracturing the femora in mice young The proliferation was at a maximum after 32 hours

In our study there was a significant increase in labelled cells as early 4 hours after the fracture, reaching a maximum after 20 hours in the area near the fracture On the other hand, a later response seemed to occur in the area away from the fracture, where the number of *labelled cells did not reach a maximum until 28 32 hours had elapsed*

On the contralateral control bone there was a slight increase initially in labelled cells, but thereafter the number was constant and low The increase did not coincide with the response in the fractured bone However, as compared with the periosteum on the tibiae of two non-traumatized mice, the periosteal layer was thicker and more cellular

In other words, the results indicate that a fracture initiates a factor which acts as an inductor upon the osteogenic cells, at first locally, but the reaction at a distance from the fracture as well as the mild response in the contralateral bone might indicate that a universally active factor is operative as well

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Table 1 Sex and age at time of accident

Age (years)	Males	Females
4–19	3	4
20–39	10	2
40–59	5	0
60–78	4	4
Total	22	10

Table 2 Cause of accident

Fracture	Low	High
Motor car	14	4
Motor cycle	0	2
Moped	1	0
Bicycle	1	1
Run over	3	0
Fall	3	3
	22	10

Table 3 Displacement of the odontoid process as seen on X ray films

Displacement	Forward	Backward	Right	Left	Total pts
2–4 mm	8	1	1	1	12
5–9 mm	7	2	1	–	10
10–25 mm	2	2	–	–	4
Angulation					
3–9°		–	4	4	8
10–19°	3	–	–	1	4
20–29°	5	2	–	–	7
30–34°		3	–	–	3

varying severity. Two did not consult a doctor until a few days after the accident and another 2 were given physical therapy for pain in the neck. Three had acute operation under anaesthesia for other injuries without the fract... as [illegible] ...days later and in four 3–7 weeks after the accident. A total of 21 patients (66 per cent) had to be examined by tomography on one of the first days. In 10 cases the first X ray films were assessed as being normal.

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FRACTURE OF THE ODONTOID PROCESS OF THE AXIS

J Husby & K Harry Sorensen

Accepted 14 viii 73

The diagnosis and treatment of fractures of the odontoid process still pose many problems The injury is potentially fatal or may entail extremely serious neurological complications, but such complications may be completely avoided by early diagnosis and adequate treatment

Odontoid fractures make up around 13 per cent of all fractures affecting the cervical spine (Amyes & Anderson 1956) and they are being diagnosed with increasing frequency (Nachemson 1960), mainly because of the increasing traffic intensity (Amyes & Anderson 1956 Schatzker et al 1971)

The fracture was not recognized primarily in 6 out of Amyes & Anderson's 63 cases, in 4 out of Nachemson's 26 cases, and in 2 out of Schatzker et al 's 37 cases

Where treatment is concerned the views are still controversial as to the indication for conservative *versus* operative treatment, and the reported frequency of non-union has varied widely

MATERIAL AND METHODS

During the 10 year period 1961–1970 32 patients with fracture of the odontoid process were treated in the Departments of Neurosurgery and Orthopaedic Surgery in Odense The age distribution and sex ratio are shown in Table 1 Sixty nine per cent are from the last 4 years This is due to the increasing traffic intensity 81 all the women were under 20 or over 60

In the five two year periods 0 6 4 13 and 9 patients were treated Thus 67 per cent are from the last 4 years This is due to the increasing traffic intensity 81 per cent having sustained their fractures in traffic accidents (Table 2) mostly motor car accidents Only 6 patients sustained the fracture by falling one at floor level and 5 from heights varying from less than half a metre to an air crash

Nineteen patients were unconscious for a short time but awake at admission and 4 were unconscious for a long time Practically all the conscious patients complained of occipital pain and stiffness but these complaints were of highly

Table 4 Treatment

	Fracture	
	Low	High
(Reduction under anaesthesia)	(2)	(2)
Collar	8	1
Hanging head (2 months) + collar	4	–
Cranial traction + collar	3	1
Bed rest + collar	3	–
Cranial traction (fracture of femur)	1	–
Fusion + Minerva-jacket	–	7
Fusion + collar	1	1
	20	10

bent head because of anterior displacement In practically all nine cases the position improved All patients except for one child, were treated subsequently with a collar (of leather or plastic) until an average of 6½ (3–11) months after the accident (Table 4)

Nine patients underwent posterior fusion of C1–C2 but two of them of C1–C3 After the sutures had been removed a Minerva jacket was worn for 4 months, later for only 3 months Thereafter, the patients wore a collar until 7 (3–11) months after the accident Fusion was performed on all patients with high fractures

Only one patient with a high odontoid fracture was not subjected to operation This was a 63 year old woman with rheumatoid arthritis treated with *cortisone* over a period of 10 years who had been in a motor car collision Several wounds were sutured under anaesthesia Thereafter, the odontoid fracture was diagnosed The odontoid process was dislocated 25 mm backward In the Department of Neurosurgery it was reduced to a normal position without anaesthesia The cranial traction slid off because of osteoporosis so that fusion was abandoned After bed rest for two months with the head between sand bags re-dislocation occurred New reduction was impracticable, as the atlantal arch had sunk down behind the body of the axis Four years later after the patient had constantly worn a plastic collar she had no subjective complaints and mobility was good There were no neurological deficits

Technique

Since 1965 we have been using a special operative technique for posterior cervical fusion The neurosurgeon (J.H.L.) and orthopaedic surgeon (K.H.S.) operate jointly The patient is placed in the prone position with cranial traction and face support The posterior arches of the atlas and axis are exposed by a midline incision and their cancellous bone is exposed 2½ cm to each side From the wing of the iliac bone two bone grafts are removed 25 mm wide and 30–40 mm long (Figure 2), comprising just over half the crest and the external lamina with underlying cancellous bone which is removed in a groove shape just beneath the crest to fit the subsequent site of the atlantal arch A groove is created in the cancellous bone



Figure 1 X-ray film of a fracture of the odontoid process of the axis in a 23-year old man who had run his car into a tree at a speed of 140 km/h, without a safety belt The odontoid process was displaced 15 mm and tilted 23° forward No neurological deficit
A low, unstable odontoid fracture which united after fusion, preceded by cranial traction with the odontoid process displaced 2 mm forward, not tilted

Radiologically only 4 fractures were non displaced, whereas in 24 cases there was displacement of the axis and in 18 cases angulation Out of 17 anteriorly displaced fractures 8 were simultaneously tilted, the tip of the odontoid process pointing forward Of five cases with posterior displacement 4 were tilted backwards As is apparent from Table 3, the displacements were by no means slight In 14 cases there was an axial displacement of the odontoid 10-25 mm in relation to the atlas and head as measured on the X-ray film (but in fact less marked), and in 14 cases there was a 10–34° angulation of the odontoid Initially the displacement may have been greater, especially in traffic accidents (*Figure 1*)

Other injuries were demonstrated in more than half the cases Six had other cervical fractures, several of which were multiple, but all were stable One developed herniation of the 6th cervical disc, 4 sustained a slight cord injury causing in three very mild persisting neurological deficits Nine sustained extremity fractures and three chest injuries Two had fairly mild cerebral contusion, and three had cranial fractures In ten patients pre-existing degeneration and narrowing of cervical discs were demonstrated

Treatment

In the matter of treatment we made a distinction between *low* and *high* fractures The low fractures are generally more stable, having a broad, often irregular fracture surface proceeding down into the body and to the sides at its base The high fractures are in fact invariably unstable and unite poorly, as the area of the fracture surface is smaller, the fracture being situated in a kind of 'neck' The stability was evaluated by traction on the head without anaesthesia under fluoroscopy, using flexion extension on 7 low and 2 high fractures The odontoid process was mobile in 2 low and in the 2 high fractures Under anaesthesia 2 low fractures and a high one were reduced One high, greatly displaced fracture was reduced without anaesthesia

Twelve patients were treated by bed rest for about two months five of them with cranial traction, whereas four were positioned on a double mattress with backward-

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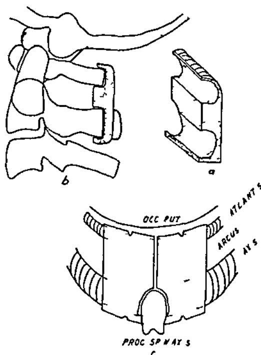


Figure 2 Drawing of the fusion The graft (a) trimmed into fashion The graft in situ viewed from the lateral (b) and posterior (c) aspect

rather more inferiorly at the site of the contact surface of the axial arch The two grafts are placed cancellous surface forward against the two arches one on the right and one on the left side in such a way that the cristal edge just fits over the upper margin of the atlantal arch and the two grooves fit the two arches On a level with the base of the spinous process of the axis the medial edges are cut off the grafts and centrally on the upper and lower edge of the two grafts a small notch is created for a 0 35 mm thick twined steel wire already placed in front of the arches of the atlas and axis both on the right and on the left side While tightened with wire tiers first the right and then the left steel wire is tied separately so that the grafts are firmly pressed against the arch and the non removed cancellous bone projects between the two arches preventing them from being pressed together and thus preventing angulation at the site of the fracture Finally a free end of the steel wire from the right and left knot is tied transversely above and the other two ends below the spinous process of the axis respectively (Figure 3) In our hands this technique has proved simple and reliable

RESULTS

Thirty patients attended follow up 8 years 13 months after the accident Two had died One succumbed 8 days after the accident to pulmonary embolism (extremity fracture) Autopsy showed the odontoid process to be firmly wedged into the body The other patient died



Figure 3 A 17 year old girl with a fracture of the odontoid process of the axis X ray film of fusion viewed from the lateral (a) and anterior (b) aspect Solid union of the graft 3 years after the operation Note the steel wire arrangement and the graft which projects between the arches of C1 and C2

two years after the accident, then aged 78, of arteriosclerotic heart disease He had primarily undergone posterior fusion of a high unstable odontoid fracture which had apparently united in a normal position eight months later These two patients had not had any neurological deficits

Among the remaining 30 followed patients 14 were entirely symptom free Sixteen had subjective complaints, in most cases mild and not incapacitating These complaints were pain, fatigue, or restricted mobility No patient had developed secondary neurological signs Only one patient was completely disabled having constant pain and marked, pain-conditioned fixation of the cervical spine The odontoid process had united with an 8 mm posterior displacement, tilted 34° backward and 8° to the left There was incongruence and a narrow joint space on the left between the atlas and axis The patient refused an offer to have fusion performed The patients had been off work for an average of 7 months after the accident (those who had been treated by fusion for only 6 months)

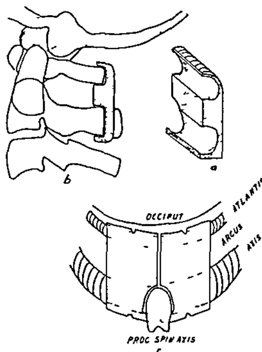


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Table 5 Results as regards union

Union	Primary position of odontoid process			
	Displaced/angulated		Normal position	
	Conserv tr	Fusion	Conserv tr	Fusion
Position unchanged	11	1		
Position improved	–	5		
Position deteriorated	1	–		
Position anatomic correct	5	1	2	1
Non-union	3	1*		
	–	–	–	–
Total 30	19	8	2	1

* os odontoideum

The mobility of the cervical spine for flexion + extension averaged 109° for conservatively and 91° for operatively treated patients Lateral flexion to the right and left was 64° and 44°, and rotation was 112° and 76° respectively The minimum distance from the chin to the manubrium sterni was 0–2 cm in 17 patients, 2–5 cm in 10, and 5–8 cm in only 3

Union was confirmed by tomography in 18 out of the 30 patients The results as regards union may be seen from Table 5· Out of 19 primarily displaced and conservatively treated fractures 11 had united in an unchanged position, 5 in an anatomical, and one in a negligibly poorer position, whereas 3 had not united Eight primarily displaced fractures were treated by fusion, all showed solid union In addition, the odontoid fractures had united in 7 cases (in an improved position in 6) In the last patient treated by fusion an os odontoideum had not united, and indeed this could not be expected Three primarily non-displaced fractures united in an unchanged position

Three out of 30 fractures, or 10 per cent, had failed to unite One of these patients was described above Another patient, aged 65, treated with a plastic collar for only 3 months, showed non-union with instability 15 months after the accident Fusion was then carried out, and 6 months later there was solid union of the fusion as well as pseudarthrosis In the third patient radiography 4½ years after the accident showed that union was not solid, but there was no instability of the odontoid process The patient was symptom free and working and had in the meantime sustained two severe head injuries, so fusion was not suggested

DISCUSSION

Thus our investigation has confirmed that fractures of the odontoid process of the axis occur most often in traffic accidents most com monly in men and that the injury is increasing in frequency, as also reported by Amyes & Anderson (1956), Nachemson (1960) and Schatz ker et al (1971)

We have also been able to demonstrate the difficulties in diagnosing the fracture The explanation is that pain in the neck and fixation are not always sufficiently marked to draw attention to this site as the patients are often suffering from multiple injuries Radiographical ly the fracture is not uncommonly overlooked partly because other fractures of the skull or cervical spine call attention to themselves and partly because the first films taken in the acute situation may be of a poor quality For diagnostic purposes it is contra indicated to take primarily lateral views in forward and backward flexion According to our experience tomography should be used to a far greater extent than hitherto For several years at the Odense Hospital routine films of the cervical spine have been taken in the acute situation of all patients even with mild concussion or a suspicion thereof and thereby several odontoid fractures have been disclosed The reason why a relatively large number of our fractures were diagnosed at a late stage is that a number of the patients had primarily been treated elsewhere As early as 1935 Meyerding advocated X ray examination of the cervical spine in all patients with mild pain at the back of the neck after head injury

As for treatment widely differing principles have been suggested Blockey & Purser (1956) advised reduction during cranial traction maintained for 6 weeks and followed by 6 weeks in a Minerva jacket Five of their eleven patients exhibited non union but the authors did not feel there was an indication for treating it particularly by fusion as the non union was not considered dangerous and as no late com plications had occurred Amyes & Anderson (1956) also advised con servative treatment of all patients according to the same principles but maintaining immobilization until radiological union at least for 6 months using posterior atlanto-axial fusion only if stability was not attained in 9 months After adequate treatment they had no late com plications but 5 per cent developed non union owing to inadequate treatment

Alexander et al (1958) emphasized that fusion protected against

late complications, but stated that fractures proceeding into the body may unite satisfactorily without operation

Nachemson (1960) found three months' immobilization to be sufficient, but eight out of his 18 patients had non-union after an average period of 11 years These patients had less complaints than the others, and treatment by fusion was not felt to be indicated

Schatzker et al (1971) also used 4–6 weeks' cranial traction, followed by 6 weeks in a Minerva jacket or a collar, but they found non-union in 14 out of 22 cases, whereas 2 of 15 posterior atlanto axial fusions by the technique of Gallie (1939) failed to unite, and in 9 cases the odontoid fracture had also not united After experimental investigations these authors classified the fractures into high and low, according to whether they were estimated to be above or below the accessory ligaments However, the frequency of non union proved the same in both groups, but invariably highest in cases of displaced fractures Thus, the classification into high and low fractures was not used in selecting the therapeutic method These authors advised fusion in the event of non-union, if the patients are to lead normal lives

In more recent materials the tendency to operative treatment is on the whole stronger This must be viewed on the basis of a greater risk of another trauma to pseudarthroses in the great traffic intensity of our times Thus, Hentzer & Schalimtzek (1971) have reported that the risk of secondary spinal cord injury must be considered to be great in non-union They reported two patients with non union who secondarily sustained cord injury, fatal in one case

Thus, it is difficult to avoid non-union, but the risk involved in it may apparently be obviated by performing fusion, also in cases where the non union of the odontoid process nevertheless persists According to our findings, as well as those of others, long lasting follow up is needed after conservative as well as operative treatment, and union has to be verified by tomography at least 6 months after the accident, and up to that time a bandage has to be worn However during the last 3 months it is usually sufficient to wear Camp's plastic collar

In our experience the treatment should consist of fusion in all cases of high fracture and, if anatomical reduction and fixation cannot be maintained, also in cases of low, unstable fractures Posterior atlanto axial fusion may be performed without increasing the risk, even in elderly persons, and it affords the most favourable results when carried out by a neurosurgeon and an orthopaedic surgeon jointly It is not necessary to extend the fusion to the occipital bone, blocking movements between the head and the atlas

SUMMARY

At the Departments of Neurosurgery and Orthopaedic Surgery, Odense Hospital, Denmark, 32 patients were treated for fracture of the odontoid process of the axis during the eight-year period 1963 1970 Sixty-nine per cent were males

Traffic accidents were responsible in 81 per cent of the cases In 28 per cent the diagnosis was made 4 days to 7 weeks after the accident Tomography was often necessary for the diagnosis Twenty-four fractures were displaced (max 25 mm), and 24 were angulated (max 34°) Four patients had slight contusions of the spinal cord

Twenty-one were treated conservatively, nine by a collar and twelve by bed rest In nine patients posterior cervical fusion was done by a special technique, followed by a Minerva jacket for 3 months Most patients were treated subsequently with a collar for up to 6 months after the accident All high fractures except one were treated by fusion using a special technique

The 30 surviving patients were re-examined 13 months to 8 years after the accident Fourteen were symptom free, whereas 15 had slight complaints One patient was totally incapacitated None had late neurological deficits

Twenty seven fractures had united, 12 in the original position, one in a more displaced position, and nine in a normal anatomical position Three non operated cases had failed to unite (10 per cent)

The authors advise routine X-ray examination of the cervical spine in all patients with concussion or admitted because of a suspicion thereof and tomography if there is a suspicion of odontoid fracture, so that this fracture is not overlooked as often as in the past Posterior atlanto axial fusion is advised in all high and certain unstable low fractures All patients should be immobilized for a minimum of six months and the union should be verified by tomography

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ROTATION OSTEOTOMY OF THE SHAFT OF THE HUMERUS FOR RECURRENT DISLOCATION OF THE SHOULDER: ANTERIOR AND POSTERIOR

G K Chaudhuri, A Sengupta & A. K. Saha

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One of the methods for restoration of dynamic stability is by rotating the upper fragment after osteotomy of the shaft of the humerus, externally in recurrent anterior dislocation and internally in recurrent posterior dislocation (Saha 1961, 1967, 1969 and 1971).

Similar restoration should be possible by rotating the lower fragment after osteotomy in the opposite direction The following sixteen cases demonstrate that the rotation of the lower fragment is equally effective (Figures 1, 2 and 3)

MATERIAL

Sixteen cases were selected for rotation of the lower fragment after transverse osteotomy of the shaft of the humerus Fifteen had recurrent anterior dislocation of whom six were spontaneous and the remaining nine had a traumatic first episode One case had spontaneous recurrent posterior dislocation He could dislocate at will by adduction while the glenohumeral joint was flexed at 100°.

Selection was made on the basis of investigation Fifteen cases had retrotorsion from 32° to 48° The remaining case, who had posterior dislocation, had 14° retrotorsion The glenohumeral indices were within normal limits The glenoid tilt was 0° in four cases and 4° to 15° posteriorly in eleven cases and in one case 8° anteriorly Four of the cases belong to the Bengal Police Service

METHOD

All cases had a transverse osteotomy of the shaft of the humerus and, except one, the distal fragment rotated internally through an angle of between 20° and 30° The case with recurrent posterior dislocation had the distal fragment rotated externally through 25° to make the joint stable while adducting in a flexed position (the

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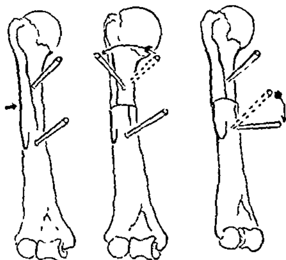


Figure 3 Reduction of retrotorsion after osteotomy may be either by rotating the upper segment outwards or the inner segment inwards in recurrent anterior dislocation

to be effective it should take bite of both the cortices Therefore, the site of osteotomy selected was quite low This procedure was followed till 9 2 72, and considerably reduced the time for union In two cases no plaster immobilisation was necessary

In order to make the osteotomy site sufficiently high the compression plate is reversed so that the oblique screw points downwards (Figure 4) This procedure enables us to get (a) fixed high site of osteotomy and (b) effective compression due to the oblique screw taking bites of both the well formed cortices

On account of the follow up being less than one year, the cases are not reported

RESULTS

Those cases with low osteotomy took 2½ to 9 months for union The remaining cases took 3 to 6 weeks for clinical union Some of these had compression plates After rehabilitation they had full range of movement and no recurrences All the members of the Police force included in this series have gone back to their normal duties (Table 1)

CONCLUSION

Osteotomy with internal rotation of the lower fragment is equally effective in preventing recurrent anterior dislocation and gives a stable



Figure 1 Axial skiagram of the normal glenohumeral joint in 120° abduction and full external rotation showing a small part of the articular surface near lesser tuberosity and adjoining postero superior sector of the humeral head in contact with the glenoid Most of the articular surface is anterior to the glenoid cavity Dynamic stability of the joint is maintained normally in this precarious state if the power of horizontal steerers glenoid tilt and retrotorsion are optimum

reverse of that of recurrent anterior dislocation) Osteotomy sites were low in four cases and high in the remainder The latter by itself reduced the time of union

Special compression plates (Sengupta et al 1972) were used in nine cases with the oblique screw pointing upwards toward the head The cortex of the shaft near the neck is thin and gradually merges with the spongy bone below the articular surface of the head of the humerus In order for the compression given by the oblique screw



Figure 2 Axial skiagram of both the glenohumeral joints in 120° abduction and full external rotation The contact surface is increased in a case of recurrent anterior dislocation by operative reduction of retrotorsion of the right humerus from 48° to 18° On the unoperated side though the skiagram is identical with that of Figure 1 dynamic stability is normally maintained as there is no recurrent anterior dislocation

Table 1

Name	Age in years	Side	Onset S spontaneous T traumatic	Date of onset	Recurrences	Retrotorsion	Glenoid tilt A anterior P posterior	Glenohumeral indices vertical	transverse	Date of operation	Compression plate used	Speed of union (in months)
Recurrent anterior dislocation												
M K.	21	R	T	1968	many	48°	0°	76%	59%	3 2 70	No	6
D D	22	R	T	1967	many	35°	4° P	73%	58%	19 2 70	No	3½
P M	20	R	S	1968	many	40°	5° P	77%	58%	2 4 70	No	3
A R	36	L	T	1965	many	32°	8° P	76%	59%	23 7 70	No	9
A C.	15	L	T	1970	6 times	35°	6° P	75%	56%	13 8 70	No	2½
B M	21	R	S	1968	5 times	37°	8° P	81%	60%	27 8 70	No	2½
M R	25	R	T	1966	many	40°	8° P	75%	56%	9 2 71	Yes	1½
N D	28	L	S	1968	30 times	38°	5° P	–	–	11 2 71	No	2½
O A	30	L	T	1967	22 times	40°	0°	–	–	15 3 71	Yes	1
A H	22	R	T	1969	12 times	40°	0°	–	–	17 3 71	Yes	1
A R	26	L	S	1966	5 times	42°	5° P	–	–	10 4 71	Yes	1
A B	18	R	S	1970	3 times	36°	0°		–	4 5 71	Yes	1
R A	17	L	T	1970	4 times	40°	8° P	–	–	20 10 71	Yes	1
A M	25	L	T	1960	many	35°	6° P	78%	56%	19 1 72	Yes	¾
S D	34	R	S	1959	60–70 times	38°	8° A	79%	58 3%	9 2 72	Yes	1
Recurrent posterior dislocation												
A C	26	L	S	19 [illegible]	many	14°	15° P	76%	57%	28 10 72	Yes	1

rotated internally In one case of recurrent posterior dislocation it was rotated externally This restores the stability of the *glenohumeral* joint.

The time of union was minimised by high osteotomy and use of a special compression plate

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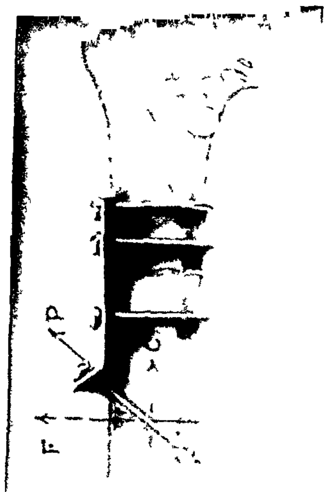


Figure 4 After rotation osteotomy the fragments are fixed by a special compression plate The oblique screw should point downwards to take bite of both the well formed cortices Thus the osteotomy site is fixed and high

glenohumeral joint To facilitate union, the site of osteotomy should be high and a special compression plate should be used

One case of recurrent posterior dislocation of the left glenohumeral joint was treated where the lower fragment was rotated externally in the opposite direction This case had right recurrent anterior dislocation which was treated by latissimus dorsi transfer in 1966 with excellent results and no recurrence to date It was seen in the follow up radiograph that the contact surfaces of both the glenohumeral joints were increased and comparable in adduction and abduction

SUMMARY

Fifteen cases of recurrent anterior dislocation with gross retrotorsion of the upper end of the humerus were selected for rotation osteotomy In all of these after transverse osteotomy, the distal segment was

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OSTEONECROSIS IN THREE YOUNG MEN PREVIOUSLY TREATED WITH STEROID FOR APLASTIC ANAEMIA

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Accepted 19 vi 73

Zinn (1971) has submitted the results of the Swiss Multi-Centre Study Group's work on idiopathic ischaemic necrosis of the femoral head in adults He calls the condition a multi-factorial disease, stating that its aetiology remains a matter of speculation

Below follow brief reports on necrosis of the humeral and femoral heads in young men who had previously been treated with steroid for aplastic anaemia

CASE REPORTS

Case 1 A farm bailiff born 1935 Apart from chronic otitis he had always been in good health In April 1958 admitted with aplastic anaemia after having washed horses 6 times *inter alia* with 25 *per cent arsenic* trioxide, during the preceding month Leukocyte agglutination was demonstrated in the serum on addition of arsenic trioxide and 0 037 mg arsenic (As) (Gutzeit) per l urine

He was treated with dimercaprol, blood transfusions, and steroid During the first 6 months he received 50–250 mg prednisone *daily, during* the next 6 months 15 mg daily Thereafter, he was off medication for 6 months During the subsequent 4 months he was again given prednisone 15 mg daily, and then he had a year without medication Then again for 2 months 100–250 mg daily, and the treatment was concluded (in March 1963) after 20–25 mg prednisone daily for 18 months

In 1958 splenectomy was performed

After the patient had suffered for some months from pain in the right shoulder and right hip joint, an X ray examination in February 1963, revealed necrosis of the head of the right humerus and both femoral heads (Figures 1, 2, and 3) The changes progressed during the subsequent months

In May 1964 he had a Moore arthroplasty of the left hip On histological examination the removed femoral head showed distinct necrosis of the bone and bone marrow Figure 4) In October 1964 a similar operation was done on the right hip This prosthesis had to be removed in August 1965 because of osteitis with fistulation In March 1967 the patient succumbed to cerebral haemorrhage Autopsy showed the spine to be uniformly, maximally hypoplastic but without collapse The right humerus was removed for examination (Figures 5 and 6)

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Figure 4 Histological specimen from the left hip of Case 1 showing a necrotic bony trabecula surrounded by vital bony tissue Haematoxylin eosin × 125 Incidentally the microscopic examination showed in places large necrotic areas in the bony trabeculae as well as bone marrow peripheral proliferation of connective tissue and widespread fibrosis No vascular changes were observed



Figure 6 Histological specimen from the right humerus of Case 1 showing empty lacunae in necrotic bone Haematoxylin eosin × 500 Moreover there was extensive myelofibrosis with necroses and haemorrhages and in places newly formed bone



Figure 5 Photo of the cut right humerus of Case 1 showing necrosis of the head



Figure 1 Right hip from Case 1 showing necrosis and collapse of the femoral head



Figure 2 Left hip from Case 1 showing necrosis but fairly well preserved contours of the femoral head



Figure 3 Right shoulder from Case 1 showing necrosis and collapse of the humeral head

Case 2 Printer s apprentice born 1949 Since 1965 severe abuse of alcohol hashish LSD and various sedatives Towards the end of 1967 the patient took 10 tablets of Endoxan® at a time for euphorizing purposes In October 1967 he was admitted with aplastic anaemia There was no evidence of lead poisoning In October 1967 steroid therapy was instituted prednisone 10 mg 4 times daily At the end of one month



Figure 9 Right hip from Case 2 with necrosis and collapse of the femoral head



Figure 10 Left hip from Case 2 showing necrosis of the femoral head but preserved configuration

Case 3 Labourer born 1947 who had been doing various odd jobs on land and at sea most recently in a varnish factory

In October 1967 the patient had idiopathic hepatitis while in prison He was treated for 4–6 weeks with Durabolin® 25 mg daily No further investigations were performed

In June 1968 he was admitted with aplastic anaemia and treated with prednisone 10 mg 3 times daily until December 1968 when the dose was lowered to 2½ mg twice daily to be discontinued 2 months later



Figure 11 Right and left hips from Case 3 Necrosis of both femoral heads



Figure 7 Necrosis of the right humeral head from Case 2 with preserved contour of the head



Figure 8 Necrosis of the left humeral head from Case 2 with collapse of the humeral head

the dose for two weeks was raised to 100 mg 3 times daily and thereafter it was gradually lowered first to 50 mg twice daily and then to 15 mg daily for 6 months and thereafter the treatment was discontinued

Splenectomy was performed in December 1967

In March 1970 necrosis of both femoral and both humeral heads was demonstrated by radiography (Figures 7 8 9 and 10) At that time the patient had been suffering from pain in all four joints for an unstated number of months

In May 1970 exploratory arthrotomy on the right hip joint was performed There were large soft masses of synovial tissue overgrowing the cartilage in several places Histological examination revealed degenerative cartilaginous changes with fibrous invasion at the periphery and the bony trabeculae contained empty lacunae with no signs of regeneration

In December 1970 arthrodesis of the right hip was carried out

Incidentally the patient continued his severe and completely uncontrollable abuse of various drugs

SUMMARY

Three young men developed osteonecrosis after having been subjected to steroid therapy

A 28 year old man had necrosis of both femoral heads and one humeral head At the time he was on steroid therapy for aplastic anaemia of 5 years' duration

A 20 year old man had necrosis of both femoral and both humeral heads Three years previously he had had steroid therapy for aplastic anaemia

A 21 year old man had necrosis of both femoral heads One year previously he had had steroid therapy for aplastic anaemia

These cases allow no conclusions concerning a causal relationship between aplastic anaemia and osteonecrosis, but a theoretical possibility is indicated

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In April 1969 the patient suddenly developed pain in the region of the right hip The pain got gradually worse in the course of the next 6 months, and at the same time pain appeared also in the left hip X-ray examination revealed necrosis of both femoral heads (Figure 11) Operative treatment was not performed

DISCUSSION

Necrosis of the femoral and humeral heads still remains a puzzling disease which has been increasing greatly during the past 20 years (Merle d'Aubigné et al 1965, Fisher & Bichel 1971). Many authors have pointed out that during the same period there has been a marked increase in the use of steroids, but their role in the development of femoral and humeral head necrosis is still a matter of discussion (Boettcher et al 1970, Sutton 1968)

That the risk of developing osteonecrosis following renal transplantations depends upon the amount of steroid administered seems to have been demonstrated by Harrington et al (1971)

The explanations of the steroid effect have differed Vasoconstriction (Labram 1963), emboli of hepatic fat (Jones & Engleman 1967), reduced remodelling following microtraumas (Frost 1965), or reduced protective oedema in the bone marrow (Riniker & Huggler 1971)

However, two-thirds of the idiopathic necroses of bone still occur unpreceded by steroid therapy, and have been related to numerous conditions (Zinn 1971) Riniker & Huggler (1971), on the basis of histopathological studies, have emphasized the role of the bone marrow in the development of femoral and humeral head necrosis They state that unlike fatty tissue, haemopoietic tissue is able to distribute a pressure arising in the bone marrow without ischaemia arising in the area, a factor of decisive importance especially in the presence of osteoporosis The risk of femoral or humeral head necrosis is said to be greatest during a rapid diminution of the thickness of the bony trabeculae if the bone marrow does not contain haemopoietic tissue

On the basis of X-radiation experiments and bone marrow grafting in animals, Knopse & Crosby (1971) have asked whether aplastic anaemia is a disease of the microcirculation rather than of the stem cell

The present three cases of steroid treated aplastic anaemia followed by osteonecrosis permit no conclusions regarding a causal relationship between the three parameters, but the two studies mentioned above might indicate such a possibility

SUMMARY

Three young men developed osteonecrosis after having been subjected to steroid therapy

A 28 year old man had necrosis of both femoral heads and one humeral head At the time he was on steroid therapy for aplastic anaemia of 5 years' duration

A 20 year old man had necrosis of both femoral and both humeral heads Three years previously he had had steroid therapy for aplastic anaemia

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TRAUMATIC DISLOCATION OF THE HIP

Results of Conservative Treatment

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Accepted 31.vii 73

Traumatic dislocation of the hip is occurring with an increasing incidence but still it is a rare injury. Former investigations on the subject are frequently based on materials collected from several hospitals, representing varying methods of treatment. The limited number of cases, in connection with the variety of therapeutic methods employed, complicates the assessment of the different methods of treatment. The main purpose of the present study is to evaluate the results obtained by conservative treatment.

MATERIAL

There were 49 patients with 49 non-central traumatic dislocations of the hip treated in the Copenhagen County Hospital, Glostrup, during the 10-year period from October 1959 to October 1969 At the time of the follow-up, 4 of the 49 patients were living outside Denmark and could not be traced The remaining 45 patients were examined clinically by the authors, and in 38 cases X-rays were made of both hips with frontal, lateral and if possible Lauenstein's projection

The minimum follow-up period was 2 years, the maximum 11, and the average 4 5 years During the first 5 years of the survey there were 17 cases, whereas during the second half of the survey there were 32 cases, an increase of 88 per cent The youngest patient was 2 years and the oldest 68 years old, nearly half the patients were aged 21–40 at the time of trauma (Table 1)

There were 42 males and 7 females 42 patients had posterior dislocation and 6 anterior, whereas one case could not be grouped In 33 cases the left hip was dislocated, in 16 cases the right hip

In 40 cases the dislocation was caused by traffic accidents dashboard dislocation occurring in 27 cases i e 60 per cent Among drivers there was a marked predominance of left hip dislocations, of 22 drivers 17 sustained a left hip dislocation Other causes were accidents at work (6 cases) and sports (one case) In 2 cases the dislocation was caused by a fall in the street

There were 12 cases of dislocation only, in the remaining 37 cases (76 per cent) the dislocation was complicated by fracture of the acetabulum (31 cases) or

Table 1 Distribution of 49 cases of dislocation of the hip by age

Age at time of trauma	No
2 20	8
21–40	23
41–60	13
61–68	5
Total	49

fracture of the femoral head (6 cases) (Table 2) Complete sciatic nerve injury occurred in one case in 2 cases there was injury to the peroneal nerve However these 2 patients had a comminuted fracture of the homolateral fibular head Significant associated injuries to other parts of the body occurred in 30 cases

TREATMENT

In all cases closed reduction was performed In 2 patients with multiple injuries the reduction was delayed 2 days because of lack of recognition of the dislocation Apart from these 2 cases the reduction was performed within 6 hours in most cases within 2 hours after trauma In 2 cases closed reduction was followed by an operation fixing a large acetabular fragment

The routine method of treatment after closed reduction was skeletal traction on the tibial tuberosity for approximately 8 weeks Because of the high incidence of other injuries the routine method of treatment was not employed in all cases Of the cases followed up 30 including the 2 operated cases were treated with traction for 6–12 weeks 9 cases were treated with traction for 3–4 weeks and 5 cases with bed rest for 4–8 weeks including one case with hip spica Thereafter, weightbearing was gradually resumed over approximately 4 weeks During the whole period of treatment active mobility was maintained in hip and knee joints The period off work was 2 12 months average 4 months

RESULTS

Follow-up

The results were judged by clinical methods and the patients were divided into four groups A, B C and D, according to the result at the time of the follow up The clinical criteria for evaluating the results are summarized in Table 3 If the criteria disagreed as to the result, the case was assigned to the poorer group

The group of completely recovered patients (group A) makes up 36 per cent (Table 4) In 11 of the 20 cases in group B, the only finding was a subjective complaint of occasional, slight sensations in the hip Patients in groups A and B were considered to have acceptable results,

Table 2 Distribution of 49 dislocations of the hip by type

	Type of dislocation	No
I	Dislocation only	12
II	With minor avulsion fracture of acetabular edge	6
III	With other acetabular fracture	25
IV	With fracture of femoral head	6
	Total	49

while in groups C and D the results were considered poor Eighty per cent had acceptable results (Table 4), characterized by no complaints or insignificant subjective complaints, no limitation or at most 10° limitation of movement in the hip, and occupation unchanged Twenty per cent had a poor result, characterized by *bothering or severe pains*, limitation of movement in the hip of more than 10°, and occupation *changed or receiving disablement pension* Omitting the 2 operated cases, the percentages shift to 79 and 21 respectively, thus representing *the results in the cases treated by conservative methods*

Of the 45 patients followed up, 38 were X-rayed In Table 5, the X-ray findings are compared with the *clinical grouping of results* All patients, except one, with either no changes or capsular calcification only had clinical results in groups *A* and *B* Many patients had one or more of the following X-ray changes exostosis, sclerosis and cyst-formation in the acetabulum or femoral head In some cases these changes possibly represented posttraumatic arthritis, while in others the changes were due to an acetabular fracture which healed with excessive formation of callus However, the results were not influenced to any large extent by these X-ray changes

There were no cases of total necrosis of the femoral head, while in 4 cases X-rays showed localised changes in the weightbearing part of the

Table 3 Criteria for evaluating results

Result	Subjective complaints	Limitation of movement in hip	Occupation
A	none	none	unchanged
B	insignificant	10° at most	unchanged
C	bothering pains	10–30°	changed
D	severe pains	more than 30°	changed or patient disabled

Table 4 Results in 45 cases of dislocation of the hip

Result	No	Per cent of followed up patients	
A	16	36	80
B	20	44	
C	5	11	20
D	4	9	
Total	45	100	

head The changes consisted of flattening and irregularity of the articular surface, combined with subchondral sclerosis and cystic areas of decreased density Two patients developed these changes in 2 years, one patient presented the changes 7 years after trauma, and in one case the dislocation was complicated by an avulsion fracture of the lower third of the femoral head These 4 patients (10 5 per cent of X-rayed cases) were over 45 years of age at the time of trauma

Results in different types of dislocations

A comparison between types of dislocations and results is shown in Table 6 Patients with dislocation only (type I), or dislocation complicated by minor avulsion-fracture of the acetabular edge (type II), all had acceptable results (groups A and B), whereas an increasing proportion of cases with other acetabular fractures (type III), or femoral head fracture (type IV) had a poor result (groups C and D) This difference in outcome between types I and II and types III and IV is statistically significant (Fisher's test, P 0 05)

Table 5 Results compared with X ray findings in 38 cases

X ray changes	Result A	B	C	D	Total
normal hip	9	6	–	–	15
capsular calcification	1	2	–	1	4
acetabular fracture not healed	–	–	2	–	2
exostosis sclerosis, cysts	4	8	–	1	13
necrosis of femoral head	–	–	2	2	4
Total	14	16	4	4	38

Table 2 Distribution of 49 dislocations of the hip by type

	Type of dislocation	No
I	Dislocation only	12
II	With minor avulsion fracture of acetabular edge	6
III	With other acetabular fracture	25
IV	With fracture of femoral head	6
	Total	49

while in groups C and D the results were considered poor Eighty per cent had acceptable results (Table 4), characterized by no complaints or insignificant subjective complaints, no limitation or at most 10° limitation of movement in the hip, and occupation unchanged Twenty per cent had a poor result, characterized by bothering or severe pains, limitation of movement in the hip of more than 10°, and occupation changed or receiving disablement pension Omitting the 2 operated cases, the percentages shift to 79 and 21 respectively, thus representing the results in the cases treated by conservative methods

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More than half of the cases in the present study were dashboard dislocations sustained by drivers or front seat passengers Funsten et al (1938), who introduced the term dashboard dislocation, found that front seat passengers were liable to get right hip dislocations, whereas we found a marked predominance of left hip dislocations in drivers

Considering that in the majority of our cases the dislocation was due to the usually severe traumas sustained in traffic accidents, it is not surprising that 76 per cent had complicating fractures of the acetabulum or femoral head, and 61 per cent had significant injuries to other parts also The incidence of complicating acetabular or femoral head fractures is high compared with other series, in which it has ranged from 40 to 60 per cent (Buus 1938, Bohler 1954, Lamke 1970)

The prognosis may be said to be on the whole favourable, 80 per cent of the patients had acceptable results, 36 per cent were entirely free of symptoms All cases of dislocation only, or dislocation complicated by minor avulsion fracture of the acetabular edge had acceptable results, but other acetabular fractures and especially femoral head fractures were poor prognostic signs This is in accordance with the findings of other writers (Thompson & Epstein 1951, Lamke 1970)

X ray changes judged to be partial necrosis of the femoral head were found in 4 patients all of these had a poor clinical result In most other cases the X ray findings were in poor accordance with the clinical findings

In the case of dislocations only, the treatment usually described in the literature consists of closed reduction followed by bed rest or traction for 2-4 weeks, most writers (Bohler 1954, Jarne 1950, Lamke 1970) being unable to demonstrate any beneficial effects from prolonged non weightbearing Our findings do not differ from the findings of these writers In dislocation complicated by acetabular fracture some authors recommend closed reduction followed by traction (Bohler 1954 Aston 1971) or plaster spica (Charnley 1965) Charnley states that the acetabular fractures usually reduce themselves when the hip is reduced However in a few cases where the acetabular fragment is large or redislocation occurs, open reduction and osteosynthesis may be necessary Other investigators (Epstein 1961, Waller 1955) recommend operation in all cases of acetabular fractures except minor ones

In the present study the predominantly conservative methods of treatment gave acceptable results in 80 per cent of all cases

Table 6 Results in different types of dislocation

Type of dislocation	Result				Total
	A	B	C	D	
I	7	4	–	–	11
II	4	1	–	–	5
III	4	14	4	2	24
IV	1	1	1	2	5
Total	16	20	5	4	45

Results related to methods of treatment

In order to compare the influence of the various conservative methods of treatment upon the results for the different types of dislocations, we divided the therapeutic methods into three groups (Table 7) The table shows that all patients with dislocations types I and II had acceptable results (groups A and B combined), regardless of the treatment In patients with dislocations types III and IV the results were better in the group treated with traction over 6–12 weeks The number of cases in the two other groups, however, was too small to allow any definite conclusions The 2 operated cases are omitted from Table 7, both had a result in group B

DISCUSSION

As a result of the increase in traffic accidents, traumatic dislocation of the hip is encountered more frequently

Table 7 Comparison between type of dislocation result and type of conservative treatment following closed reduction

Type of dislocation	Result	Treatment			Total
		Traction 6–12 weeks	Traction 1–4 weeks	Bed rest or plaster 4–8 weeks	
I+II	A+B	10	3	3	16
	C+D	–			–
III+IV	A+B	13	4	1	18
	C+D	5	2	2	9
	Total	28	9	6	43

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THE RICHARDS COMPRESSION AND SLIDING HIP SCREW SYSTEM IN THE TREATMENT OF INTERTROCHANTERIC FRACTURES

TAGE SAHLSTRAND

Accepted 4 viii 73

A gradual shift towards an increased number of elderly people in our society leads among other things to an increased frequency of inter trochanteric femur fractures In the choice between a conservative or an operative treatment of these fractures the latter method has recently been more and more recommended its great advantage being that it allows early mobilization of the patient more frequently The importance of this is obvious In order to be able to mobilize the patient as soon as possible after the operation a method of fixation should be chosen which offers the greatest possible stability The Richards compression and sliding hip screw system seems to fulfil this demand better than other methods (Clawson 1964 Dahlberg et al 1970 Bosacco et al 1972 Friedenberg 1972) For this reason this method of fixation has been employed as a routine treatment of intertrochanteric fractures since March 1971 at the Department of Surgery Central Hospital in Halmstad

In this article experiences and results obtained during the first 12 months in which the method was employed will be described The results will be compared with those of the preceding 12 month period when McLaughlin osteosynthesis was the routine method of treatment

METHODS

The implant consists of a round lag screw with a worm screw thread at the distal end and a longitudinal groove in the shaft corresponding to a ridge inside the bored out cylindrical portion of the angled plate Consequently after the plate has been slipped on to the screw and affixed to the femoral diaphysis the screw cannot rotate or change its angle in relation to the plate The screw can however

SUMMARY

Of 49 patients with traumatic non-central dislocation of the hip, 45 were examined after a lapse of 2 11 years, average 4 5 years Sixty per cent were dashboard dislocations Of these cases, drivers were found more liable to sustain injury to the left hip There was a high incidence of complicating fracture of the acetabulum or femoral head, such injury occurring in 76 per cent of the cases All patients were treated with closed reduction, in most cases followed by 6–12 weeks traction, and 4 weeks of gradually increasing weightbearing At the follow-up 80 per cent had acceptable clinical results, and 36 per cent were entirely free of symptoms Acceptable results occurred in all cases of dislocation only, or dislocation complicated by minor acetabular avulsion fracture, whereas other acetabular fractures and especially femoral head fractures were poor prognostic signs

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Postoperative physiotherapy including quadriceps exercises and movement of the hip and knee joint was started the day after the operation. Mobilization to walking with in principle full weightbearing on the operated leg was generally allowed for stable as well as comminute fractures on the 7th to the 10th day after the operation. Anticoagulants have as a rule been given as prophylaxis against thrombosis until the patient has been satisfactorily mobilized.

During the preceding year, when McLaughlin osteosynthesis was the routine method, mobilization normally started later and full weightbearing on the operated leg was not permitted until callus was seen roentgenologically.

Table 1 Distribution of age and sex

Richards material				McLaughlin material			
Age	♂	♀	Total	Age	♂	♀	Total
<50	2	–	2	<50	–	1	1
50–54	1	–	1	50–54	–	–	–
55–59	1	2	3	55–59	–	–	–
60–64	2	–	2	60–64	–	1	1
65–69	1	1	2	65–69	–	3	3
70–74	–	8	8	70–74	2	4	6
75–79	2	4	6	75–79	2	6	8
80–84	1	5	6	80–84	1	8	9
85–89	1	4	5	85–89	1	2	3
90–94	2	4	6	90–94		3	3
Total	13	28	41	Total	6	28	34

Table 2 Other serious disease on admission

Disease	
Cardiovascular disease	6
Orthopaedic disease	12
Neurological disease	2
Psychiatric disease	1
Malignant disease	1
Autoimmune disease	1
Eye disease	1
Acute trauma	2

MATERIAL

A total of 41 patients—13 men and 28 women—were treated with the Richards compression and sliding screw system during a one year period beginning in March 1971. Stable and comminute intertrochanteric fractures were included in the study. The last mentioned were in a minority. The average age was 75 years (range 39–94 years). Sixty three per cent (26/41) of the patients suffered from other serious diseases on admission.



Figure 1 Routine radiographs after completion of Richards osteosynthesis on a intertrochanteric fracture

slide axially in relation to the plate ('telescope') during the process of healing of the fracture The lag screws are of various lengths from 6 30 to 11 25 cm and the plates, which are forged at fixed angles from 135 degrees to 155 degrees in 5 degree increments are also of various lengths, from 2 hole to 5 hole plates for routine use and extra long lengths for special applications The most useful combination has proved to be, in our experience, the 3 and 4 hole plates with an angle of 135–140 degrees and 8 75 cm lag screws

The fracture is reduced on the extension table and surgery performed with the aid of TV image intensifier observation The required length and position of the lag screw are determined by means of a guide pin The correct guide pin angle is obtained by means of an adjustable angle guide instrument which is positioned on the lateral shaft of the femur In this way, stress forces between the screw and the plate are avoided when the two piece device is assembled and the plate is screwed on the femur A channel through the central part of the femoral head corresponding to the diameter of the lag screw and a cortical hole corresponding to the diameter of the cylindrical portion of the plate are made with special reamers A special screw insertion wrench is utilized to insert the lag screw which should be one cm shorter than the depth of the reamed channel in order to allow sufficient compression of the fracture After the plate has been slipped on to the lag screw and fixed to the femoral shaft with bone screws the surgical procedure is finished by impacting the fracture with a special compression screw The radiological appearance after finished osteosynthesis is shown in Figure 1 a and b

Table 4 Classification of ability to walk

Grade 1	Walk without support
Grade 2	Walk with one cane
Grade 3	Walk with two canes crutches, trestles walker or living support
Grade 4	Confined to bed or wheelchair

Table 5 Ability to walk before and after operation

Grade	Before	After
1	23	9
2	4	15
3	2	5
4	0	0

Table 6 Ability to walk before and after operation

1 → 1	1 → 2	1 → 3	2 → 2	2 → 3	3 → 3
9	12	2	3	1	2

Follow up study was made by means of a questionnaire 6–18 months after the operation The ability to walk before and after the operation was compared and classified as shown in Table 4 (in 2 cases no information about the ability to walk could be obtained) Prior to the injury 6 patients (21 per cent) had a reduced ability to walk In 14 cases (48 per cent) the ability to walk remained unchanged in 13 cases (45 per cent) it deteriorated by one grade and in 2 cases by two grades (Tables 5 and 6) The proportion of patients discharged from the hospital either to their homes or to the convalescent home at the hospital (where the patients get their meals cooked but otherwise have to look after themselves) is probably a representative measurement of the functional as well as the social *rehabilitation* This proportion was found to be 69 per cent

In the McLaughlin series 2 cases of unsatisfactory and unstable osteosynthesis occurred The average operation time was 10 minutes shorter Wound infection occurred in 2 cases The average hospital stay was 57 days and the preoperative preparation time 4 days The proportion of patients discharged either to their homes or to a convalescent home was 43 per cent

This group was compared to 34 patients—6 men and 28 women—with intertrochanteric fractures treated the preceding year according to the McLaughlin method Stable and comminute fractures were included in this material too The number of stable and comminute fractures were proportionally equal in the two materials The average age in this group was 77 years (range 45 93 years) and 47 per cent suffered from other serious diseases on admission

RESULTS

In only one case was the osteosynthesis unsatisfactory This patient had multiple injuries and was in poor general condition including delirium tremens Treatment of the intertrochanteric fracture subsequently had to be postponed for 3 weeks This resulted in unsatisfactory reduction of the fracture contributing in a decisive way to the unsatisfactory and unstable osteosynthesis No secondary complications due to the implant were observed, and in no case was it necessary to remove it afterwards One advantage of this sliding nail technique compared to the McLaughlin technique is that the problem of the nail penetrating the hip joint is theoretically non existent However this trouble was not seen in our McLaughlin material either not even in those three patients with unstable osteosynthesis because weightbearing was postponed long enough The average operation time among 7 surgeons was 85 minutes from the moment when the incision was made to the moment when the wound was closed Wound infection occurred in 2 cases Seventy nine per cent of the patients could lie on the operated side without pressure pain in the operation scar

Table 3 Cause of death

Cause	
Heart insufficiency	4
Heart insufficiency + Pneumonia	1
Pneumonia	1
Pyelonephritis	-
Pulmonary embolus	1
Malignant disease	1

Nine patients died in the hospital another patient died from malignant disease after discharge The total mortality rate during an observation time of 6–18 months was thus 24 per cent (10/41)

The average hospital stay of patients who could be discharged from the hospital either to their homes or to a convalescent home was 38 days 4 of which were used for preoperative preparation

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DISCUSSION

The Richards compression and sliding hip screw system provides sufficient stability in most cases of intertrochanteric fractures to allow early postoperative mobilization of the patient The firm fixation of this technique usually converts an unstable fracture to a stable one Rehabilitation is easier and more effective if the elderly patient is allowed to bear weight on both legs If there is a restriction to partial weightbearing on the operated leg it is often difficult for many patients in this age group to adjust weightbearing as needed In view of the circumstances mentioned above and the observations reported by Clawson (1964), our patients with stable as well as comminute or before the operation unstable fractures were instructed to carry full load on the operated leg Ambulation was deferred until 7–10 days after the operation, mainly because the postoperative pain reaction has normally receded to a satisfactory extent by that time No serious complication resulted from this way of postoperative treatment In only one case did unsatisfactory osteosynthesis require a delay of mobilization Because of advanced age and a poor general condition a few patients were mobilized within the first few days after the operation

The end results including ability to walk are comparable to those of other series treated with the same method (Clawson 1964, Bosacco et al 1972) Of the two patients whose ability to walk deteriorated by two grades, one underwent amputation of the lower leg because of gangrene in the foot a short time after the hip surgery The only case of unsatisfactory osteosynthesis deteriorated by one grade This patient had multiple injuries including a tibial fracture on the opposite side

Comparison of the Richards and McLaughlin groups in the present series clearly demonstrates the advantages of the Richards method More favourable results were obtained in the group operated on with the Richards method because of fewer cases of unsatisfactory and unstable osteosynthesis, and a reduction of average length of hospital stay by 19 days Furthermore the proportion of patients discharged from the department of surgery straight to their homes was increased by 26 per cent The 10 minutes longer operation time in the Richards group may be explained by the fact that the method was new to our clinic when the investigation period began, whereas McLaughlin osteosynthesis had been used for many years when the comparison period began

CONCLUSION

Results of using the Richards compression and sliding hip screw system in the treatment of intertrochanteric fractures are reported. The method has proved that it can stabilize the fracture to such an extent that it has been possible to mobilize the patient to walking with full weightbearing on the operated leg within a few days. The results have been compared with those obtained previously when McLaughlin osteosynthesis was used as the routine method. Obvious advantages of the Richards osteosynthesis were observed in the form of a better fixation, a shorter length of hospital stay and an increased proportion of patients who could be discharged from the department of surgery straight to their homes. Rehabilitation has thus been facilitated and improved with consequent positive effects for patients and savings of hospital resources.

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EXTRACTION SET

A Method for Removing Acrylic Cement from the Medullary Cavity

T. J. J. H Slooff & K Lindner

Accepted 27 ii 73

The cementing of endoprostheses has become a generally accepted procedure in surgery of the hip (Chapchal 1972) With the increasing frequency of these allo arthroplastic interventions, loosening of the prosthesis is an increasingly observed complication (Bonnin 1972, Wilson et al 1972)

Total extraction of the loosened implant is the only correct treatment in these cases, and removal of the acetabular component with the cement usually poses no problems However, the situation is different for the femoral component, whose cement coat does not traverse the medullary cavity at all levels because the internal shape and diameter of this cavity are not the same at all levels

The literature comprises few data on the technique of extraction in these cases The ultimate objective is a Girdlestone operation It is advised that, for removal of the acrylic cement from the medullary cavity of the proximal femur, a bone chip should be chiselled from the cortical wall (Buchholz 1972)

We have devised a method of extraction of the acrylic cement which leaves the cortical wall intact and simplifies the operative procedure Given a homogenous, unfragmented cement coat, the subtrochanteric cement can be extracted in its totality with a set of instruments developed for this purpose (Figure 1)

The set consists of three self tapping rods of increasing diameter, a universal hand-piece three long drills matching the self-tapping rods, one awl, one slotted hammer and three sharp Charnley type spoons A detailed view of the heads of the self-tapping rods and drills is presented in Figure 2

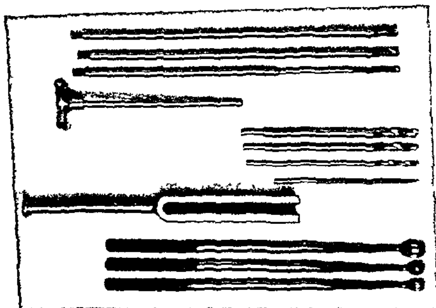


Figure 1 The extraction set

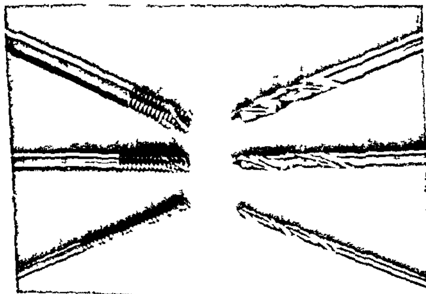


Figure 5 Detail of the self tapping rods and drills

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Figure 4 Acetabular and extracted femoral cement mass

the cement coat Next the universal hand piece is used to insert the matching metal rod which at its tip is self tapping and further up has a normal broad thread Once the rod is sufficiently deep and tight the implant can be extracted in its totality by short strong blows of the slotted hammer (Figure 4)

If necessary detached cement fragments and the lard like layer of connective tissue which has often formed between the cement and the cortical wall can be removed with the aid of the sharp spoons

In problematic cases in which the cement has been normally implanted in the medullary cavity whereas the prosthesis has been introduced by a fausse route all extrafemoral cement can be chiselled off whereupon the bore of the medullary cavity is increased and the cement removed following the above mentioned method

SUMMARY

This paper describes a set of instruments for extraction of acrylic cement from the medullary cavity of the proximal femur in cases of loosened cemented endoprostheses

DESCRIPTION OF THE OPERATIVE TECHNIQUE

The approach to the hip is made preferably through a postero-lateral incision according to Gibson-Kocher The often markedly thickened capsular regenerate is excised in its totality so that luxation of the head-neck prosthesis becomes possible The latter can be knocked loose *from the cement coat by a few short, hard blows on a punch If* necessary, the acetabular prosthesis with the attached cement can then be removed from the acetabulum

The femur should be so presented that one can look into the tract of the prosthesis stem All visible cement (mostly attached to the trochanter) should be removed with the aid of a chisel or osteotome particularly cement localized in the shoulder of the femoral neck (see cross-hatched leaf osteotome in Figure 3)

Only after removal of this cement can a guide wire be passed straight into the medullary cavity along its axis (see dotted line in Figure 3 *right position*), and the bottom of the cement coat can be seen The awl is used to perforate the bottom (cooling is required), whereupon the drills are carefully used to increase the bore of the stem tract The choice of drills depends on the type of prosthesis and the thickness of

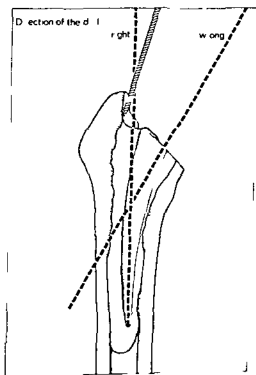


Figure 3 Position for osteotome and drill



Figure 4 Acetabular and extracted femoral cement mass

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GROWTH OF THE UPPER END OF THE FEMUR

Experimental Investigation in the Rabbit

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Pathological conditions of the hip involving the epiphysis of the femoral head may lead to growth disturbances which affect the shape and the length of the upper end of the femur Acute infections of the hip in infants epiphyseal changes following reduction of congenital dislocation of the hip Perthes disease or fractures of the femoral neck in children may be followed by the occurrence of a coxa vara deformity and a variable amount of shortening of the femur

The shortening is the direct outcome of the deceleration and eventual cessation of growth at the epiphyseal plate of the capital epiphysis The coxa vara deformity too results from the cessation of growth of the capital epiphysis but also from the continued growth of the unaffected trochanteric epiphysis with subsequent rise of the tip of the trochanter above the level of the head

Such elevation of the greater trochanter reduces the efficiency of the abductor muscles of the hip and thus produces a gluteal limp In order to prevent this occurrence early surgical epiphysiodesis of the trochanter has been recommended by Edgren (1965) and Langenskiold & Salenius (1967) This step was justified by the studies of Laurent (1953) which showed that the epiphysis of the trochanter does not contribute to the length of the femur and therefore could be dispensed with easily However the observations of Morgan & Somerville (1960) indicated that the trochanteric epiphysis was active in maintaining the length of the femur in conditions affecting the capital epiphysis such as those mentioned above

It seems therefore that there is still some uncertainty with regard to the contribution of the trochanteric epiphysis to the length of the femur. Nevertheless, the implications thereof are important. By performing an epiphysiodesis of the trochanter in cases of progressing coxa vara deformity we may well prevent the occurrence of a gluteal limp It is not at all certain, however, that through such action we may not aggravate the existing shortening by discarding the sole remaining and active epiphysis of the upper end of the femur.

This report concerns an experimental study undertaken in order to ascertain the changes in length of the femur occurring after resection of the capital epiphysis, a situation somewhat similar to that existing in the above-mentioned pathological conditions. In addition it was thought that a resection of the trochanteric epiphysis and the study of the subsequent changes in length of the femur may throw some light on its importance as a growth centre of that bone.

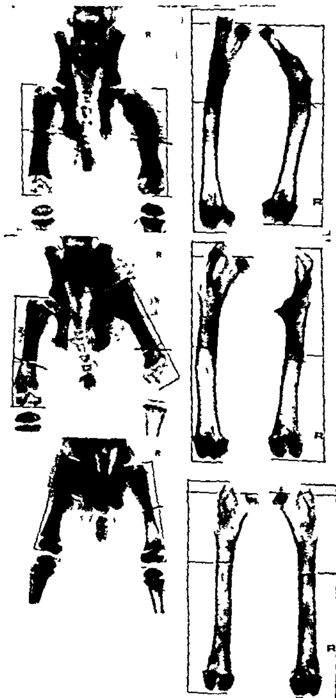
METHODS

Rabbits of both sexes about twelve days old with average weight of 230 grams were used All rabbits belonged to eighteen parturitions of eighteen dams The siblings of each parturition were divided into three groups In the first group (group T) the right trochanteric epiphysis was resected through a small incision in the gluteal region The muscles were cut from the trochanter, the trochanteric epiphysis was exposed and sharply resected, encroaching upon the bony metaphysis Only the skin was sutured by interrupted stitches In the second group (group H) the right capital femoral epiphysis was resected The skin incision was similar, the gluteal muscles were split, the joint capsule was exposed and opened dorsolaterally The femoral head was dislocated after severance of the ligamentum teres and through external rotation of leg, the cartilagenous head was sharply resected encroaching upon the bony metaphysis and the skin closed by interrupted sutures The third group (group C) was kept as controls

All operations were performed under open ether anaesthesia While the rabbits were under anaesthesia a bone marker was introduced percutaneously into the femoral shaft The marker was the sharp end of a stainless steel hypodermic needle 27 gauge and 1 8 cm long (B D Yale Luer Lok Becton Dickson and Company, Rutherford, N J) Bone markers were introduced into both femurs of all the animals

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Figure 1 Measurements used in each of the three groups on the first and last roentgenograms
Top row trochanter resected group
Middle row head resected group
Bottom row control group
For details see text



Roentgenograms were taken within forty eight hours following operation (or following marking for the control animals) A mobile x ray apparatus was used (Picker X-Ray Corporation, Cleveland, Ohio) Exposure time was 0 08 second and the distance between tube and x-ray cassette was 113 cm Each rabbit was radiographed dorsoventrally, strapped to a special board, with hindlimbs fully extended and symmetrical as far as possible

During the ensuing months additional roentgenograms were taken mainly in order to ascertain that there was no change in the position of the markers These radiograms were not used for measurements

The animals were killed at the age of six months Each pair of femurs was dissected free of the soft tissue and a final roentgenogram was taken in the same conditions

The measurements were performed on the initial and final roentgenograms between the following points (Figure 1)

For group T in which the trochanteric epiphysis was resected the total length was measured from the uppermost point of the femoral head to the lowest point of the longest femoral condyle and the lengths of the upper and lower parts were measured from these points to the marker inserted into the shafts,

For group H in which the capital epiphysis was resected the total length was measured from the uppermost point of the trochanter to the lowest point of the longest femoral condyle and the lengths of the upper and lower parts were measured from these points to the marker inserted into the shaft,

For the control group (group C) all the preceding measurements were taken

The effect of specific operation on the growth of the femur was evaluated by way of comparing growth in the operated group with that observed in the control group, using the t-distribution for significance tests

The dam was considered as the sampling unit (Weil 1970) Therefore the comparison was made between mean growth of each dam's siblings in the operated group with the mean of the same dam's siblings in the control group

In addition the difference in growth within pairs of femurs was evaluated for each group For this evaluation t tests were also carried out using the young rabbits as the sampling unit

RESULTS

Averages of femoral growth are presented by siblings and groups (operated and control) in Table 1 (for the proximal end) and Table 2 (for the distal end)

Table 3 and Figure 2 present the average differences in longitudinal growth between siblings in the control group and in each of the two operated groups

In group T in which the trochanter was resected, as compared to the control group, the growth of the proximal end was significantly smaller (the average difference was — 4 2 mm) and the growth of the distal end was significantly greater (the average difference was 4 4 mm) No

Table 1 Averages by siblings of longitudinal growth (in mm) in the proximal end of the femur

Serial no of dam	Operated groups						Control group		
	No of siblings	Unoperated femur (LT)	Trochanter resected femur (RT)	No of siblings	Unoperated femur (LT)	Head resected femur (RT)	No of sib lings	LT	RT
1				3	34.7	29.0			
2	2	29.5	24.0	3	34.7	32.0	1	26.0	31.0
3	2	21.5	22.0	2	29.0	31.0	2	27.0	27.0
4	2	28.5	23.5				1	34.0	30.0
5	3	23.7	21.7	2	28.0	26.5	2	21.5	24.5
6	1	24.0	26.0						
7				1	34.0	30.0	2	29.5	29.0
8	2	26.5	21.0	1		25.0	1	25.0	27.0
9	2	26.0	22.5	2	30.0	28.0	1	27.0	
10	2	28.0	22.5	2	32.0	25.0	1	30.0	27.0
11	2	25.0	20.5	1	26.0	24.0	2	21.5	20.5
12	1	24.0	22.0	1	33.0	25.0	1	23.0	23.0
13	1	22.0	20.0						
14				1	27.0	25.0	2	22.5	25.5
15	2	24.0	18.0	3	28.7	20.0			
16	2	20.5	22.0	2	26.0	23.5	2	23.0	22.5
17	3	20.7	18.7	2	28.5	25.5	2	25.5	21.0
18	1	26.0	19.0	2	30.5	28.0	2	27.0	26.5

significant difference was found between the unoperated femur in this group and the corresponding left femur of the control siblings

In group II in the femurs in which the femoral head was resected there were no significant differences in longitudinal growth from femurs in the control group, neither in the proximal nor in the distal ends (the average difference was 1 1 mm for the proximal end and 1 5 mm for the distal end) However, a significant difference was found between the unoperated femur in this group and the corresponding left femur of the control siblings in that the proximal end of the unoperated femur grew significantly longer (the average difference was 4 6 mm)

Table 4 presents the average differences in growth within pairs of femurs in each group In group I and in group II growth of the proximal end of the operated femur was significantly smaller than in the unoperated left femur (the average difference was 3 1 mm in group I and 3 7 mm in group II) In group I, the growth of the distal end was

Table 2. Averages by siblings of longitudinal growth (in mm) in the distal end of the femur

Serial no. of dam	Operated groups						Control group		
	No. of siblings	Unoperated femur (LT)	Trochanter resected femur (RT)	No. of siblings	Unoperated femur (LT)	Head resected femur (RT)	No. of siblings	LT	RT
1				3	51.0	49.7			
2	2	46.0	51.0	3	47.3	47.3	1	40.0	37.0
3	2	46.5	44.5	2	37.0	30.5	2	41.5	42.0
4	2	44.5	48.0				1	42.0	43.0
5	3	42.3	43.0	2	41.5	39.5	2	43.0	39.5
6	1	37.0	38.0						
7				1	45.0	50.0	2	58.5	46.0
8	2	49.5	50.5	1		44.0	1	46.0	44.0
9	2	45.0	45.5	2	45.0	44.5	1	46.0	
10	2	45.5	52.0	2	45.5	47.5	1	49.0	50.0
11	2	38.5	42.5	1	40.0	41.0	2	36.0	37.5
12	1	36.0	37.0	1	39.0	42.0	1	36.0	34.0
13	1	45.0	44.0						
14				1	37.0	36.0	2	41.0	39.5
15	2	35.0	35.0	3	32.7	39.3			
16	2	35.5	38.0	2	34.5	37.0	2	33.5	33.0
17	3	37.7	40.7	2	40.5	44.5	2	43.0	41.5
18	1	43.0	47.0	2	45.5	46.0	2	45.0	44.5

significantly greater in the operated femur (the average difference was 2.1 mm).

The difference in total length between right (operated) and left (unoperated) femurs in group 3 was negligible (average 1.1 mm). The

Table 3. Averages (and standard errors) of differences in femoral growth (in mm) between operated and control siblings

End of femur	Unoperated femur		Operated femur	
	Trochanter resected vs control group	Head resected vs control group	Trochanter resected vs control group	Head resected vs control group
Proximal	0.9 (3.3)	4.6 (2.6)*	−4.2 (2.7)*	1.1 (1.9)
Distal	0.8 (3.4)	1.2 (5.2)	4.4 (3.7)*	1.5 (5.6)
Whole femur	−0.1 (5.3)	3.4 (6.8)	0.2 (4.2)	2.6 (5.8)

* Significant at 5% level

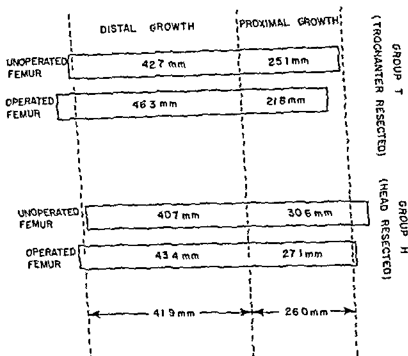


Figure 2 Diagram demonstrating the average differences in femoral growth between operated and control siblings. The distances from the middle horizontal broken line to the upper and lower broken lines each represent respectively the growth in proximal and distal ends in the control group

value of this difference was significantly greater in group H, the unoperated femur in group H being longer that the operated one (average 3.2 mm).

DISCUSSION

The roentgenological method of measurement used in this study is similar to those used by Langenskiöld (1957), by Elo (1960) and by Ryöppy (196[illegible]). According to Langenskiöld (1957) such technique permits calculations to an *accuracy of 1 mm*.

When the operated femurs were compared with those of the control group it became apparent that neither resection of the head nor that of the trochanter produced any significant reduction in the total length of the bone. However, the mechanism by which the total longitudinal growth was preserved or perhaps even somewhat *enhanced (in group H)* was different for each resection.

Table 4 Averages (and standard errors) of differences in longitudinal growth (mm) within pairs (left minus right side) in each group*

End of femur	Group		
	C (control)	T (trochanter resected)	H (head resected)
Proximal	−0 2 (2 7)	3 1 (3 5)§	3 7 (4 2)§
Distal	0 6 (2 5)	−2 1 (2 9)§	−0 5 (4 8)
Whole femur	0 4 (2 6)	1 1 (3 6)	3 2 (2 9)§

* Right is the operated side in groups T and H
§ Significant at 5% level

In animals in which the trochanter was resected the proximal end grew significantly less but the distal end grew significantly more Thus, because of the compensatory growth of the distal end no change occurred in the total longitudinal growth In animals in which the femoral head was resected the proximal end as well as the distal one of the operated femur grew even a little more than femurs in the control siblings It may be assumed that growth of the proximal end was preserved or perhaps even enhanced through compensatory growth from the trochanteric epiphysis, and therefore no reduction occurred in the final length of the femur

It appears therefore that resection of one of the upper femoral epiphyses produced enhanced growth in other epiphyses of that femur A similar effect was observed by Hall Craggs & Lawrence (1969) who found a reduction in the normal decelaration of the distal epiphysis in rabbits whose proximal epiphysis was stapled

An enhanced growth was observed in the unoperated femurs in group H in which the head was resected, due to the activity of the proximal epiphyses of these femurs Therefore, while growth of the operated femurs in this group was quite similar to that of femurs in control siblings, growth of the contralateral, unoperated femurs was greater and a significant difference in growth within the pairs of femurs resulted

Thus, by using control siblings, an enhanced growth effect was also found in one epiphysis of the contralateral, unoperated, femur Such controls are not mentioned in the work of Hall-Craggs & Lawrence (1969) and no explanation can be forwarded in this respect

The fact that neither the resection of the capital nor that of the trochanteric epiphysis produced any shortening of the operated femur

appears to unite the seemingly opposite views of Laurent (1959) and that of Morgan & Sommerville (1960). Laurent (1959) stated that the trochanteric epiphysis did not contribute to the length of the bone, because injury to that epiphysis produced either insignificant shortening in the experimental animal or even lengthening in children operated upon because of unilateral congenital dislocation of the hip. It is permissible to think, in the light of our experiments, that these results may have been due to a compensatory enhanced growth of the distal femoral epiphysis of the operated femur. Morgan & Sommerville (1960) have observed that in cases of destruction of the capital epiphysis, the trochanteric epiphysis was active in maintaining the length of the femur. This view is corroborated by our findings of uninhibited growth occurring in the operated femur after resection of the capital epiphysis.

With regard to the advisability of epiphysiodesis of the greater trochanter mentioned at the beginning, it must be pointed out that, although this study has shown that there can be quite efficient compensatory growth when one epiphysis is made deficient, it is still questionable whether such growth will occur when both *upper femoral* epiphyses are deficient, as is the case when growth disturbances of the capital epiphysis are treated by epiphysiodesis of the trochanteric epiphysis. We feel that as long as this question remains unanswered, some circumspection should be exercised before deciding on the performance of such an epiphysiodesis.

SUMMARY

Changes occurring in the length of the femur were studied after resection of the capital epiphysis or of the trochanteric epiphysis performed in young rabbits.

No shortening of the operated femur occurred in either one of these resections.

It could be ascertained that normal length was preserved through compensatory enhanced growth from other, unaffected, femoral epiphyses.

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THE TREATMENT OF FLEXION CONTRACTURE OF THE KNEE JOINT WITH POSTERIOR CAPSULOTOMY IN RHEUMATOID ARTHRITIS PATIENTS

S Jakubowski & A Dubinska

Accepted 19 vi 73

In rheumatic diseases a flexion contracture of the knee is apt to develop frequently In the initial phase the contracture can be eliminated by conservative methods, but in the course of time it may become fixed and then it is only through an operation that extension of the joint can be obtained

In cases marked by extreme tension in the flexor tendons and a fixed flexion contracture of more than 15°, one of the methods of operative *treatment is posterior capsulotomy as described by Putti in 1921 and* Wilson in 1929 and later modified by Preston in 1953 In rheumatic diseases it was Wilson who first applied it

MATERIAL AND METHOD

In the Orthopaedic Clinic of our Institute 37 patients underwent 47 posterior capsulotomies because of flexion contractures of the knee joint A total of 26 women and 11 men aged 6–67 years were operated on. Of these 20 patients with 30 operated knees underwent a follow up study 1–6 years after surgery

The angle of the contracture before the operation is shown in Table 1 In 13 knees there were coexistent deformities (valgus and/or external rotation of the

Table 1

The angle of the contracture before capsulotomy	The number of knee joints
15 30°	1
30 50°	24
50 – 90°	3
90 – 100°	2

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tibia and/or posterior subluxation) The range of movement in the majority of the patients was from 30–60° before the operation (Table 2) Out of 20 patients only 5 managed with great difficulty to walk by themselves

Table 2

The range of movement before capsulotomy	The number of knee joints
trace – 30°	6
30 – 60°	18
60 – 90°	5
more than 90°	1

The indications for posterior capsulotomy were

1 Flexion contracture of the knee joint of more than 15°, conservative treatment being without effect and there being no indication for primary synovectomy
2 mobility of at least 10–15°,
3 slight radiological alterations in the joint
4 good psychical condition and good cooperation

The following were considered as contraindications

1 Flexion contracture with absence of mobility,
2 severe radiological changes in the joint
3 lack of cooperation
4 no possibility for improving the general mobility of the patient even after capsulotomy
5 contraindications for general surgery

The technique of the operation

Through a 12 14 cm long incision on the lateral side of the thigh and knee joint tractus iliotibialis the biceps tendon (just above its insertion) and the lateral head of the gastrocnemius are severed A longitudinal incision into the joint capsule is made and the posterior recessus of the joint is opened the femoral insertion of the capsule and the periosteum are displaced proximally Sometimes the insertion of the gastrocnemius is not cut but is detached together with the capsule When there is coexistent valgus and external rotation of the tibia it is necessary to cut through the tense lateral intermuscular septum and push it up and down with a rasparatorium Sometimes we cut through the insertion of the fibular ligament A second incision is made on the medial side of the thigh and knee joint If necessary the flexor tendons (gracilis semitendinous and semimembranous) may be severed The insertion of the medial head of the gastrocnemius is cut and the posterior recessus of the joint is opened through a longitudinal incision in the capsule If necessary a transverse incision through the popliteal fascia is made and the tibial insertion of the capsule is severed Sometimes full straightening is achieved only after cutting the posterior insertion of the anterior cruciate ligament

In exceptional cases the procedure should be expanded by simultaneous debridement of the anterior part of the joint cutting the intra articular adhesions, removing the patella or doing a patella plasty

The procedure is completed by suction drainage and skin sutures only, and fixation of the extended limb in an tight plaster dressing The operation should be finished with full extension of the knee It should be mentioned however that this may be hindered by excessive tension of the nerve vessel bundle and skin

After 24 hours the suction drainage is removed and exercising of the quadriceps muscle is started On the fourth or fifth day we begin to raise the limb After one week the plaster is removed leaving it as a splint at the back of the knee in full extension for 6–8 weeks during the periods between training of the knee joint, and at night Within seven to ten days we begin with passive and within 15–20 days active flexion Walking with crutches is started when the force of the quadriceps is almost normal Full weight bearing is allowed after 6 weeks

In our procedures there were no complications during the operation they appeared however within the postoperative period In one case there was transient paresis of the peroneal nerve in three cases there were haematoma in the wound, in one case there appeared wide spread necrosis of the skin in the popliteal area, which occurred after correcting the contracture from 90 to 30°, in one case there was superficial wound infection These complications hampered extensively the orrect postoperative rehabilitation

RESULTS

1 During the operative procedure 25 knee joints acquired full extension Two knee joints had residual contracture due to errors in the operative technique Three knee joints had 30–50° of contracture because of a large initial contracture (110°, 95° and 30°) and severe tension of the neurovascular bundle and skin in the popliteal area Posterior capsulotomy in these 3 cases was considered to be preliminary to a following operative treatment (arthrodesis, supracondylar osteotomy of femur and hinge prosthesis)

2 During the time of follow-up the residual contracture left during the operation increased in 2 joints In 5 joints secondary contracture from 10 20° developed owing to difficulties in rehabilitation as a result of wound haematoma in 2 cases, and because of insufficiency of the quadriceps muscle in 3 cases In 20 knee joints full extension was obtained (Figure 1)

3 The range of movement improved remarkably The number of knee joints with a reduced range of movement decreased, but those with a range of 60 130° were increased (Figure 2)

4 After posterior capsulotomy walking was greatly improved Among 9 non walking patients before the operation only two could not walk after because of coexistent contractures in other joints of the

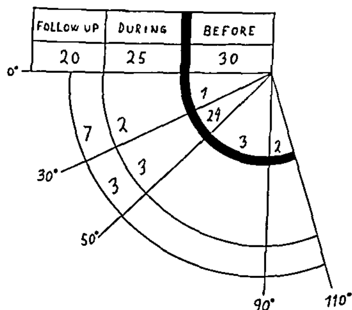


Figure 1 Angle of flexion contracture before, during and after operation

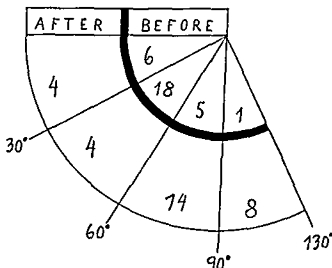
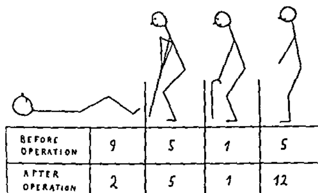


Figure 2 Range of movements before and after posterior capsulotomy

lower limb They were assigned for further operative treatment (Figure 3) It should be mentioned that in several cases flexion contractures in the hip joint were eliminated by a conservative or operative method enabling full use of the limb after posterior capsulotomy was carried out



BEFORE OPERATION	9	5	1	5
AFTER OPERATION	2	5	1	12

Figure 3 Walking before and after posterior capsulotomy

The criteria of the results were

Good The axis of the limb improved, there was full extension, the range of movement increased and walking improved

Satisfactory The axis of the limb improved, there was residual contracture up to 15°, more or the same amount of movement as before the operation and walking improvement

Bad No axis improvement contracture greater than 15°, the range of movement the same as before the operation or even reduced, no walking improvement

The results obtained 18 (60 per cent) good, 10 (33 per cent) satisfactory and 2 (7 per cent) bad Among the satisfactory results there were the three cases with gross contractures (30–50°) in which the capsulotomy was considered as a preliminary operation

DISCUSSION

To obtained good results after posterior capsulotomy, it is necessary according to Preston (1953) to adhere to the following procedures during the operation Full passive extension, reconstruction of the extensor apparatus thus enabling efficient active extension, removal of intra articular causes which make the blockade in the anterior part of the joint

In our procedure we did not apply reconstruction of the extensor apparatus to any patient In 3 patients the secondary contracture was due to inefficient quadriceps muscle, and in these cases it is supposed that reconstruction should have been carried out

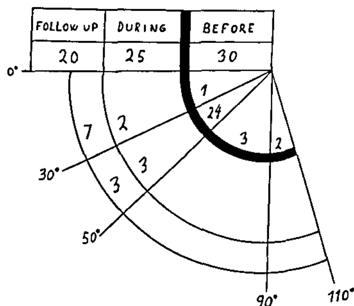


Figure 1 Angle of flexion contracture before during and after operation

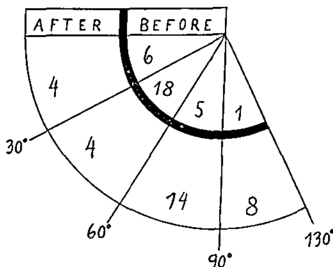


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SYNOVECTOMY OF THE KNEE

A Follow up Examination

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Synovectomy of the knee joint was first reported by Volkmann in 1877 In the last few years the number of operations of this type has increased rapidly

The indications for synovectomy of the knee joint are persistent pain and swelling, and it is done to prevent further destruction of ligaments and articular cartilage (Marmor 1966)

In rheumatoid joints all the known facts indicate a destructive factor from the synovial membrane, presumably an enzyme, is actively trying to break down the cartilage This may explain the preventive effect of synovectomy (Moberg 1969, McEwen 1971)

In a number of reports it is claimed that the clinical effect of synovectomy is good both in children and adults (London 1955, Marmor 1966 Fyring et al 1971, Walter & Vesterdal 1971) Together with the clinical improvement a thermographic and arthrographic investigation has shown reduced inflammatory activity (Goldie 1969, Taylor & Ansell 1972)

Other investigators claim that the effect of synovectomy ceases with the years This has been proved by experiments with animals and evaluation of the radioactive isotope uptake in clinical trials (Dick et al 1970 Taylor & Ansell 1972)

The task of our investigation has been to evaluate the effect of a synovectomy of the knee on the mobility of the joint, the swelling of the joint and the patients assessment of the result

MATERIAL AND METHODS

Clinical Material

At the Orthopaedic Hospital in *Arhus* 57 synovectomies of the knee were performed on 51 patients between 1963 and 1968 Six had bilateral synovectomy Two

Fulfilling the third of Preston's points, the medial meniscus was removed in 4 cases, the posterior part of the anterior cruciate ligament was cut in 3 cases, patella plasty was done in one case, the patella was removed in one case and in 2 cases the anterior part of the joint was cleaned giving the possibility of full extension.

The postoperative procedure for our patients differs from that of Preston as described above.

After posterior capsulotomy of 13 knee joints with follow up 6–24 months after the operation Preston obtained good results in 82 per cent of the cases. In our material good results were achieved in 60 per cent, satisfactory in 33 per cent; in this way improvement was obtained in 93 per cent of the cases.

CONCLUSIONS

1. Posterior capsulotomy eliminates flexion contracture of the knee joint, corrects the limb axis and expands the range of movement by the angle of the eliminated contracture.

2. It enables more efficient walking and even restores the patient's ability to walk without help.

3. As far as large flexion contracture is concerned, posterior capsulotomy may be employed as a first stage in the operative treatment.

4. Good operative technique and correct postoperative rehabilitation have a decided influence on obtaining good results.

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RESULTS

The patients were all followed up as a routine in the out patients' clinic at intervals of months to years after the operation A special examination was made for the follow up of this work This special follow up examination took place on the average 4.2 years after the synovectomy (minimum 3 years—maximum 8 years)

One of the most interesting features to record when trying to prove the value of knee synovectomy is the development of bone changes estimated by X ray examination We used the classification given under clinical assessment The result is shown in Table 1

Unfortunately 7 knee joints were not examined radiologically due to technical misunderstanding

The passive range of movement is shown in Table 2

As stated earlier all the knee joints were swollen before the operation At the follow up examination 34 patients presented with the same measurement on the operated knee as on the non affected knee

At the follow up examination the patients' own opinion of the operated knee has been recorded (Table 3)

Table 1 X ray changes evaluated before and after synovectomy

Classification	1	2	3	–X ray
Before operation	26	26	3	0
At follow up	19	18	11	7

Table 2 The changes in passive knee movement in relation to synovectomy

Classification	1	2	3	4
Before operation	33	7	14	1
At follow up	45	1	9	0

Table 3 The patients own opinion of the result of the synovectomy at the follow up examination

Excellent	15
Good	27
Fair	11
Poor	2

DISCUSSION

As regards the radiological changes we found that the greater proportion of the knees evaluated as normal before operation, remained in that group after the synovectomy

patients died before the follow up examination 55 knee joints of 49 patients were evaluated at the follow up examination The youngest patient in the material was 11 years old and the oldest 68 In the five decades between the ages 11 and 60 the numbers of patients operated on were distributed so that there were between 9 and 12 in each decade in the decade between 61 and 70 only three patients were operated upon

The indications for operation were prolonged swelling pain and tenderness and resistance to treatment by conservative and medicinal measures Operation on the knee was avoided where there was severely limited range of movement especially in cases with pronounced extension defects and with instability and in patient with severe bone changes

The diagnoses have been based on clinical examination as well as histological examination made in connection with the operation Six patients showed synovitis villonodularis pigmentosa 23 rheumatoid arthritis and 15 had a histological diagnosis synovitis chronica non specifica

Technique of Operation

The operation was done with the aid of a tourniquet and usually a lateral and medial parapatellar incision as suggested by Marmor (1969) was used In some cases and with increasing frequency an anterior transversal incision was used All accessible synovial tissue was removed which included removal of the supra patellar pouch From the posterior part of the joint as much of the synovial tissue as possible was removed The postoperative treatment has been guided knee flexion from the first day and weightbearing from about 2 weeks after the operation

Assessment of Clinical Results

The following objective criteria were used

Range of passive movement classification
grade 1 no lack of extension and flexion > 90°
grade 2 no lack of extension and flexion < 90°
grade 3 extension defect and flexion > 90°
grade 4 extension defect and flexion < 90°

X ray changes were classified as follows

grade 1 no abnormalities
grade 2 narrow joint space and/or slight bone changes near to the joint surfaces
grade 3 pronounced bone changes with destruction and/or severe arthrosis
All the knee X rays were taken with the patient in the prone position

At the follow up examination the patients evaluation was graded as follows

excellent	no subjective symptoms at all
good	knees with marked improvement compared with condition before operation
fair	knee joints which have shown slight or no improvement but the condition was not worse than before operation
poor	knee joints which are worse than before operation

RESULTS

The patients were all followed up as a routine in the out-patients' clinic at intervals of months to years after the operation A special examination was made for the follow up of this work This special follow up examination took place on the average 4 2 years after the synovectomy (minimum 3 years—maximum 8 years)

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DISCUSSION

As regards the radiological changes we found that the greater proportion of the knees evaluated as normal before operation remained in that group after the synovectomy

In evaluation of the effect of the procedure on the joint movement, we found improvement in only one quarter of the material On the other hand no cases showed deterioration.

All patients operated on had swelling of the joint; at the re-examination there was swelling only in one third of the patients.

Finally we tried to evaluate the patients' own assessment of the value of the operation. Three quarters of the patients claimed marked improvement compared with their remembrance of the condition before the knee operation.

SUMMARY

Synovectomy in a chronically swollen knee joint is a useful procedure with regard to subjective results. The procedure may preserve and sometimes restore the movement, diminish swelling and arrest development of bone changes.

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MACINTOSH ARTHROPLASTY IN RHEUMATOID ARTHRITIS

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Knee joints, damaged by injury or various forms of destructive arthritis have been treated by arthroplasty for more than 100 years, but before 1950 the results were highly unpredictable with an overall incidence of success of about 43 per cent (Young 1963) In 1950 McKeever (McKeever 1960) and Townley (Townley 1961) independently suggested replacement of the tibial plateaux by vitallium plates In 1954 MacIntosh introduced the prosthesis which is the subject of this paper Although many years have elapsed since the introduction of these hemi-arthroplasty designs, the literature contains few detailed accounts of the results which can be expected following MacIntosh arthroplasty for rheumatoid arthritis in the hands of the "average" surgeon as assessed by a doctor uninvolved in the patients' clinical care The purpose of this paper is to provide such an account on another 69 knees

MATERIAL AND METHODS

Between 1965 and 1970 the MacIntosh prosthesis was used for the treatment of rheumatoid arthritis in 69 knees in 55 patients at The London Hospital England At the time of follow up 2 patients (2 knees) had died and one patient (1 knee) could not be traced Thus 66 knees (9[illegible] per cent of those operated upon) were available for study The time elapsed between operation and follow up varied from 0 5 to 5 5 years (mean 2 8 years) Forty seven patients (61 knees) were females and 8 8 knees) males (87/13 per cent) The age of the patients at the time of operation varied from 17 to 79 years with a mean age of 55 years

All patients suffered from definite rheumatoid arthritis (Ropes et al 1959) and in all patients this was progressive and erosive As shown in Table 1 the duration of the disease was from 3 to 32 years and in the affected knee from one to 18 years In 38 patients the latex test for rheumatoid factor was positive when performed by a modification of the method of Singer & Plotz (1956) Eighteen of the patients had subcutaneous rheumatoid nodules Twenty two were receiving corticosteroid treatment at the time of operation

In evaluation of the effect of the procedure on the joint movement we found improvement in only one quarter of the material On the other hand no cases showed deterioration

All patients operated on had swelling of the joint at the re examination there was swelling only in one third of the patients

Finally we tried to evaluate the patients' own assessment of the value of the operation Three quarters of the patients claimed marked improvement compared with their remembrance of the condition before the knee operation

SUMMARY

Synovectomy in a chronically swollen knee joint is a useful procedure with regard to subjective results The procedure may preserve and sometimes restore the movement, diminish swelling and arrest development of bone changes

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manipulation under general anaesthesia was performed In uncomplicated cases the patient left the hospital after 3 4 weeks but continued physiotherapy for 3–4 months

The patients reviewed were asked direct questions regarding pain and functional capacity The knees were individually examined recording the range of motion, stability and deformity Radiographs were taken in the antero posterior position in extension and in the lateral position with the knee in extension and in flexion as close to 90 degrees as possible The sedimentation rate and the latex fixation test were recorded

Because of the variations in the basic disease process and the involvement of other joints assessment of these patients is difficult (Weinfeld 1969) In patients with severe disease changes between the pre operative and post-operative states give a more realistic assessment and this method has been used in this study In addition an assessment table was developed grading the results, irrespective of the pre operative state as "good" "fair" and 'poor" (Table 2) Thus *relative* and *absolute* results are both reported The patients' own assessment and willingness to repeat the operation were also recorded

Twenty four (28 knees) had previously been reviewed in 1968 and in 1970 Jessop & Moore 1972) Thus the present follow up provided an opportunity for an exact assessment of the progress of these patients over the years 1968 to 1971

Neither of the doctors who reviewed the patients in this study were involved in their clinical care

RESULTS

The overall results in the 66 knees available for follow up are set out in Table 3 There was broad agreement between the doctors' assessment and the patients' assessment although the patients were asked only if they regarded the results as 'good' or 'poor" Patients with good results stated that they would be prepared to have the operation again, patients with poor results stated that they would not Overall, a good result was obtained in about 45 per cent of knees

Twelve knees had had an arthrodesis or total knee replacement at the time of follow-up These knees are included in Table 3 but are not included in Tables 4 to 9 Thus Tables 4 to 9 give the results of the

Table 3 The overall results in 66 knees

	Doctors' assessment		Patients assessment	
	No of knees	Percentages of knees	No of knees	Percentages of knees
Good	25	38	35	53
Fair	15	23	—	—
Poor	26	39	31	47

Table 1 Duration of the disease at the time of operation

Duration of the disease at the time of operation	In the knee (No of knees)	In the patient (No of knees)
1 5 years	20	8
5–10 years	19	12
>10 years	27	46

Pre operatively all patients suffered from pain and impaired functional capacity In all knees there was limitation of movement often associated with deformity and instability Thirty three patients suffered from disabling pain in other joints impairing their total functional capacity

Radiographs showed grade IV rheumatoid changes in 64 knees and grade III changes in 2 knees (Kellgren et al 1963) Secondary degenerative changes were often present as well

The operation was performed as described by MacIntosh (1967) The tibial insertion of the patellar tendon was partially or totally detached in about a third of the operations In 6 knees a patellectomy was performed in 5 patellectomy had been performed earlier The anterior part of the synovium was excised in 41 knees The femoral condyles were re shaped only if there were marked irregularities on their surfaces In 59 knees a prosthesis was used both medially and laterally in one medially and in 9 laterally In 2 knees the prosthesis was fixed with bone cement Suction drainage was used routinely Sixteen surgeons Consultants and their Senior Registrars and Registrars performed the operations described in this study

The postoperative treatment involved bed rest for about 5 days with a light compression bandage and a plaster backslab During this period isometric quadriceps exercises were encouraged If wound healing was satisfactory on the 5th day flexion exercises and partial weightbearing were allowed emphasizing movement rather than weightbearing If in the 3rd week flexion was less than 90 degrees

Table 2 Criteria for grading the results

Good	Pain		Alleviated partially or completely
	Flexion		>70°
	Deformity	Flexion	<10°
		Valgus/Varus	<10°
Fair	One of the following		
	Pain		Unchanged
	Flexion		<70°
	Deformity	Flexion	>10°
		Valgus/Varus	>10°
Poor	All other cases		

Table 5 Pre and post operative functional capacity

	No of knees	
	Pre-operative	Post-operative
Ability to walk		
Over one mile	2	5
Outdoors up to one mile	28	28
Indoors	2°	19
Unable	2	2
Use of walking aids		
None	17	15
1 stick	20	17
2 sticks	12	14
Crutches	3	6
Wheelchair	2	2
Ability to climb stairs		
Able	6	15
Able with difficulty	34	18
Unable	14	21
Ability to reach feet		
Able	31	32
Able with difficulty	17	8
Unable	6	14
Ability to rise from a chair with "push off"		
Able	36	33
Able with difficulty	15	13
Unable	3	8
Overall		
Able to do anything	0	8
Some limitations but independent	11	6
Some degree of dependence	°8	25
Completely dependent	15	15

corrected (Table 6) and in none of the knees with a deformity exceeding 25 degrees (8 knees) was full correction achieved In these 8 knees the results were "poor

Valgus deformity was a common pre operative finding (32 knees), but varus deformity was observed in one knee only Correction was achieved in 26 of the knees with a valgus deformity and in the one knee with a varus deformity (Table 7) All knees with a pre-operative valgus deformity exceeding 20 degrees (6 knees) had poor results

Antero-posterior and lateral instability was present in 24 and 33 knees respectively Twenty one knees displayed both forms of in

Table 4 Assessment of pain

	No of knees
Completely alleviated	22
Partially alleviated	21
Unchanged	10
Increased	1
Total	54

	Preoperative pain No of knees	Postoperative pain No of knees
No pain	0	22
Occasional pain	3	14
Pain on walking	21	9
Pain at rest	30	9
Total	54	54

54 knees in which a MacIntosh arthroplasty had functioned for 0 5 to 5 5 years

As shown in Table 4 pain was completely relieved in 41 per cent and improved in a further 41 per cent

Improvement in the overall functional capacity, shown in Table 5, was very limited, occurring mainly in patients with relatively good pre-operative function Walking ability did not improve, nor did the need for walking aids The ability to manage stairs improved but the ability to put on shoes and stockings and to rise from a sitting position in a chair deteriorated Thirty-three patients had serious limitations from other joints impairing their functional capacity but the results in these patients were not worse than in the others

The range of movement is recorded in Table 6 In 21 knees (38 per cent) the range of movement improved and in 14 it deteriorated Loss of flexion was more common in the group classified as "poor" than in the other two groups, but inadequate pain relief rather than stiffness was the factor usually responsible for a "poor" grading

In 11 knees there was a post operative extensor lag of between 20 and 60 degrees None of these patients was classified as "good"

In 42 knees there was a pre-operative flexion deformity of between 5 and 45 degrees Only in 16 of these knees was the deformity fully



Figure 1 a



Figure 1 b



Figure 1 c

Figure 1 a Pre operative radiograph. Lateral view of the knee joint in flexion affected by rheumatoid arthritis for 11 years Contour of the femoral condyles appears well preserved

Figure 1 b Post operative radiograph Lateral view of the same knee joint 2 years after insertion of Macintosh prostheses showing well marked flattening of the femoral condyle

Figure 1 c Gross destruction of the femoral condyle in the same knee 3 years after arthroplasty

Table 6 Range of movement

Flexion	No of knees
Improved	21
Unchanged	19
Deteriorated	14
Extension	**No of knees**
Full extension maintained	9
Full extension gained	16
Persistent flexion deformity	26
Developed flexion deformity	4
Total range of movement	**No of knees**
Improved	21
Unchanged	19
Deteriorated	14

stability Stability was improved in about 40 per cent of knees remaining as MacIntosh arthroplasties (Table 8) There was no relation between pre operative instability and the end result

The operation did not cause any generalized flare up nor remission of the basic disease Neither the sedimentation rate nor the latex tests were affected The number of patients on steroid treatment was smaller at review (18) than at the time of operation (22) These results are similar to the findings following simple synovectomy of the knee joint at the London Hospital (Mason 1969)

Radiologically, two sequels to the operation appeared to affect the outcome collapse of the femoral condyles and collapse of the bone supporting the prostheses Collapse of the femoral condyles, presumably due to the bone of the condyles being crushed against the metal plates on the tibia, was associated with a "poor" result Figure 1

Table 7 Correction of varus and valgus deformities

	No of knees
Corrected varus deformity	1
Persistent varus deformity	0
Developed varus deformity	3
Corrected valgus deformity	26
Persistent valgus deformity	6
Developed valgus deformity	2

Table 10 Secondary operations required following arthroplasty

Procedure			No of knees
Arthrodesis			8
Total replacement	Shiers	1	
	Freeman Swanson	3	
	Total		4
Internal fixation fractured femur			1
Exploration	Infection	2	
	Avulsed patellar tendon	3	
	Loose prosthesis	1	
	Total		6
			19 (28 %)

Although the number of operations performed by some surgeons in this study was too small to permit satisfactory comparison, there did not appear to be any marked differences between the results obtained by any of these 16 surgeons

The results in the patients reviewed in 1968 and 1970 (Jessop & Moore 1972) and 1971 are summarized in Table 9 The results deteriorated over the years mainly from the group recorded as 'fair"

Secondary operations were required in 28 per cent of knees. (Table 10)

Superficial infections occurred in 11 knees and usually cleared up with antibiotics However, in 2 knees the joint was eventually involved and removal of the prosthesis and arthrodesis was required Three knees developed deep infections *per primum* Two healed with systematic antibiotics whilst one had to be arthrodesed Staphylococcus aureus was the usual organism cultured

Two supracondylar fractures occurred during manipulation One knee required internal fixation and both had to be immobilized for an unusually long period of time Both gave "poor" results

Avulsion of the patellar tendon occurred in 4 knees in which the tendon had been partially or totally detached at operation

In one knee an unsuitably high prosthesis had been used causing pain and stiffness After revision the result was 'fair'

In one knee in which the prosthesis had been cemented in place, loosening occurred and revision had to be performed The result at follow up was fair

Table 8 Instability

	Antero posterior instability No of knees	Lateral instability No of knees
Improved	19	22
Unchanged	28	26
Deteriorated	7	6
	54	54

demonstrates this in its most extreme form and in 7 other radiographs collapse was noted to a much milder degree Contact between the femur and the inter condylar eminence of the tibia as a result of collapse of the bone supporting the prosthesis was also associated with a 'poor' result

Particular note was taken of the influence of the operative technique on the end result In 55 knees in which two tibial prostheses were inserted 22 (40 per cent) were 'good' results as compared to 3 (27 per cent) out of 11 knees in which one prosthesis had been inserted Patellectomy performed at the time of arthroplasty (6 knees) was associated with only one 'good' result (17 per cent) whilst patellectomy performed at an earlier operation (5 knees) did not influence the end result Synovectomy performed at the time of operation was associated with a 'good' result in 49 per cent of knees so treated as against an incidence of 20 per cent of 'good' results when the synovium was left in place

Manipulation under anaesthesia was performed in 34 knees The final range of movement was better in knees manipulated than in those that were not

Table 9 The results in 28 knees assessed in 1968 1970 and 1971

	1968	1970	1971
		No of knees	
Good	13	12	11
Fair	8	4	4
Poor	7	12	13
Mean duration of follow up (months)	16	36	48

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In one knee in which the prosthesis had been cemented in place, loosening occurred and revision had to be performed The result at follow up was 'fair'

DISCUSSION

We have found 14 publications describing the results of the MacIntosh arthroplasty in rheumatoid arthritis Of these publications, many are synopses of verbal communications and are too brief to form a basis for evaluation (Murray 1967, Dewar 1968, Kates et al 1969, MacIntosh 1958, 1966 and 1967, McCollum et al 1970, Lowe et al 1971, Nelson & Evarts 1971) Henderson & Petersen (1969) described their results in sufficient detail to permit some cross comparison but their study was based on only 15 patients Potter (1969) and Potter et al (1972) reported the results obtained by several surgeons using the Mckeever prosthesis in 63, and the MacIntosh prosthesis in 29 rheumatoid knees Fifty-six per cent of knees finally obtained a "good" or 'excellent result MacIntosh & Hunter (1972) reported 68 5 per cent good results in 89 rheumatoid knees Since MacIntosh was one of the originators of this operation, this result probably reflects the best that can be obtained with the procedure rather than the result that can be obtained in the hands of the "average" surgeon Finally Kay & Martins (1972) reported on 44 knees with 43 per cent good and 22 per cent satisfactory results and with relief of pain in 85 per cent

There are several reasons why our results may be less satisfactory than those in other reports These include the selection of patients the operative technique, the duration of follow up and the methods of assessment

Ideally the results of any operation should be assessed, like those of a drug, by a double blind trial Since this is impossible, it is difficult to eliminate either a placebo response or observer bias from the assessment of a surgical procedure One reason for believing that the long term results reported in this study are free from observer bias is that the doctors carrying out the final assessment were not involved in the clinical care of the patients concerned We further consider that these results, based as they are upon operations carried out by 16 different surgeons, represent the results obtainable by the average" surgeon

The only marked post-operative symptomatic improvement in this series was in pain if knees which had to be converted to an arthrodesis or to total replacement are regarded as having given unsatisfactory pain relief, pain was partially or completely relieved in 65 per cent of knees Unfortunately this pain relief can not certainly be ascribed to surgery since the alternative possibility that it represents a placebo response can not be excluded In general it is recognised that the

rheumatic disorders are at least as susceptible to the placebo response as are patients with other diseases (Mason 1962) The persistence of pain relief in those who improved in this study—up to 5 5 years—is however uncharacteristic of the placebo response which is usually short lived Wolf (1959) has, however, described improvement in 80 per cent of patients at a 5-year follow-up after an inappropriate operation which he attributed to the "placebo personality" of the surgeons concerned It may also be true that reinforcement (of the placebo effect) by repeated follow-up examination could be a factor accounting for our observations in this series Such an effect, of frequent attention and repeated measurement, has been demonstrated by Currey (1965) in a rather similar situation when studying the effect of placebo injections into arthritic joints The suspicion that pain relief in the present study may have been partly due to a placebo response is perhaps reinforced by our further finding that no functional improvement accompanied the relief of pain, since activities such as walking or climbing stairs may be less susceptible than pain to improvement by a placebo effect

In the patients in this study the range of movement was not reliably increased If the 12 knees which required a conversion to arthrodesis or total replacement are included, more knees lost movement than gained it a finding which accords with the fact that the number of patients able to reach their feet was not increased by operation It of course remains possible that had these patients not been operated upon, the progress of the disease would have reduced the range of movement still further

Valgus and varus deformities were satisfactorily improved Flexion deformities were less reliably improved Although the correction of deformity is obviously a gain, it is of relatively little use if it is not accompanied by improvement in function

The detailed follow-up carried out on 28 patients in 1968, 1970 and 1971 shows that the results tend to deteriorate with time This deterioration was particularly noticeable in patients who initially obtain a "fair result but also affected those initially graded as "good" It would appear that if a good result is to be obtained with this operation, it will be evident within the first post-operative year improvement thereafter does not occur

In attempts to improve the final results several previous authors have proposed contra indications to this procedure These are listed in Table 11 All authors have found that a flexion deformity in excess

Table 11 Proposed contraindications to the MacIntosh arthroplasty and the effect of applying the contraindications to the present study

		Nelson et al	Henderson et al	Potter et al	Lowe et al	Kay et al	MacIntosh et al	Andersson et al
Flexion deformity		yes (30°)	yes (30°)	yes (30°)	yes (20°)	yes (20°)		yes (25°)
Severe destruction of tibial plateau not compensatable		yes		yes	yes	yes	yes	yes
Severe osteoporosis		yes	yes	yes				yes
Valgus or varus deformity		yes (30°)		yes (30°)		yes (15°)		yes (20°)
Predominant femoral condylar involvement		yes			yes			
Double hemi arthroplasties			yes					
Patient chairbound			yes					
Large cysts extending into the joint				yes				
Poor quadriceps function				yes				
Immobile patella						yes		
Lateral shift of tibia				yes			yes	
Previous sepsis or ankylosis							yes	
Instability					yes			
Poor motivation							yes	
Restricted movement primary complaint					yes			
60° arc of movement or less						yes		
Number of knees in this study excluded		15	58	15	37	38	2	19
Results in the remaining knees		%	%	%	%	%	%	%
	Good	23 45	2 25	22 43	12 41	11 39	25 40	25 53
	Fair	10 20	3 37 5	11 22	7 24	3 11	15 23	8 17
	Poor	18 35	3 37 5	18 35	10 35	14 50	24 37	14 30

of 20 to 30 degrees represents a contra indication and we would concur with this. We also found, as did Nelson & Evarts (1971), Potter (1969, 1972) and Kay & Martins (1972) that a valgus or varus deformity of about 20 to 30 degrees represented a contra indication. Primary involvement of the femoral condyles has been suggested as a contra indication by Nelson & Evarts (1971), Kay & Martins (1972), and by Lowe et al. (1971). In Table 11 we show the effect of applying the contra indications listed by previous authors to the 66 knees reported in this study. It will be seen that when some contra indications are applied, particularly those of Henderson & Peterson (1969), Lowe et al. (1971) and Kay & Martins (1972), very few knees remain available for study. This suggests that the patients operated upon in this study were on the whole more severely affected than those in some previous series. When all the knees in this study to whom the various contra indications listed in Table 11 apply are eliminated, only 2 knees remain; in one the result was good, in the other poor. More realistically, some improvement is obtained if knees displaying a flexion deformity in excess of 25 degrees, a valgus or varus deformity in excess of 20 degrees, severe destruction of the tibial plateaux not compensatable by the insertion of a prosthesis and severe osteoporosis are excluded. If these criteria are applied to our study 19 knees (30 per cent of the present series) would not have been operated upon and of the remaining knees the results would have been "good" in 53 per cent.

Our findings suggest that the best results can be obtained if the insertion of the prosthesis is not combined with patellectomy but is combined with synovectomy and is followed by a manipulation under anaesthesia. Lowe et al. (1971) found that the results could be further improved by cementing the prosthesis in place.

SUMMARY

Sixty six knees in 53 patients have been assessed 0.5 to 5.5 years after MacIntosh arthroplasty for rheumatoid arthritis.

At the time of follow up 12 knees (18 per cent) had been converted to an arthrodesis or total replacement.

Pain was completely or partially relieved in 65 per cent of knees.

The range of movement was not reliably increased.

Valgus and varus deformities were satisfactorily improved. Flexion deformities were less reliably improved. Deformities of any kind in excess of 2[illegible] degrees could not be fully corrected.

In an attempt to make a total assessment, 38 per cent were graded as "good', 23 per cent as 'fair' and 39 per cent as 'poor

If the selection of patients in this study was adequate we must conclude that in the hands of the average' surgeon using the technique here described the MacIntosh arthroplasty does not appear greatly to benefit the knee in rheumatoid arthritis

ACKNOWLEDGMENT

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LITERATURE

In 1904 Lexer et al. published observations on the vessels of the talus. Contrast medium had been injected into the femoral artery. Standard X rays showed a richness of vessels within the talus. The distribution within the bone was not described.

Sneed (1925) observed a small number of vessels within the talus but did not describe any principal talar arteries.

In 1930 Wildenauer demonstrated a network of extraosseous talar vessels, which arose from the arteria dorsalis pedis, arteria tibialis posterior and arteria peronea. This network was the rete periostale which covered all surfaces of the talus excepting cartilage areas, ligamentous insertions and sulci for passing tendons. Wildenauer also described the tarsal canal to be limited by the talar and calcanear sulci. He described it as running in a posteromedial—anterolateral direction ending in the funnel shaped sinus tarsi. In this canal he demonstrated an artery connecting the arteria tibialis posterior with the arteria sinus tarsi. This vessel was called the arteria canalis tarsi. Wildenauer ascribed to this artery great importance in the nutrition of the talus.

In 1958 Haliburton et al. published observations on the vascular supply of the talus. Their injection technique also involved a filling of the veins, which were difficult to distinguish from the arteries. Wildenauer's work on the extraosseous vascular supply was confirmed. In addition an intraosseous network was demonstrated, which arose from the extraosseous vessels.

In 1970 Mulfinger & Trueta described a technique, by which only the arterial supply was demonstrated. By injecting the vessels 36–48 hours post mortem—during which time the capillary bed is destroyed by autolysis—the contrast medium did not pass over to the veins. Intraosseous anastomoses in the talus were demonstrated between the three main arteries of the lower extremity. They concluded that the most important vascular supply to the talus was by the arteria canalis tarsi and arteria sinus tarsi. They showed that the arteria canalis tarsi delivered a branch—ramus deltoideus—to the medial part of the corpus tali and they estimated that about ¼ of the body was supplied by this vessel. The head and neck of the talus received their vessels from the arteria dorsalis pedis, the arteria sinus tarsi and to some extent from the arteria canalis tarsi.

It has been mentioned that Haliburton et al. (1958) filled the venous system but there was no information on its distribution. In 1967 Crock

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THE ARTERIAL SUPPLY OF THE TALUS

LARS PETERSON, IAN GOLDIE & DAN LINDELL

Accepted 11 ix 73

Fractures of the talus can cause a disrupture of the vascularization of this bone, which may become deprived of its blood supply to varying degrees A necrosis may arise, the frequency of which varies with the type of fracture The rate of necrosis in fractures of the neck and body of the talus combined with dislocation is 30–70 per cent and in undislocated fractures 0–10 per cent (McKeever 1943, Coltart 1952, Watson-Jones 1955, Sullivan & Jackson 1958, Larsson et al 1961, Hawkins 1970, Kenwright & Taylor 1970)

In some instances there is a regression of the necrosis, but in others it persists and the talar dome collapses, especially when it is subjected to weight-bearing forces (Hawkins 1970) In cases of talar necrosis clinical improvement occurs in 80 per cent of the cases after treatment through non weight-bearing With non weight-bearing the circulation may be sufficient to favour healing, but with the talus under stress it may become so insufficient that a regression of the necrosis is impeded (Coltart 1952, Hawkins 1970, Kenwright & Taylor 1970) It is suggested that clinical improvement is due to an increased osseous healing, secondary to an improved blood supply (Coltart 1952, Watson-Jones 1955, Hawkins 1970) New arterial pathways may be opened up, which are described in this investigation

The object of this investigation has been to study the vascular sources, which contribute to the total vascularization of the talus Special interest has been devoted to the arterial pathways running in the ligaments and joint capsules between the talus and surrounding bones

In a later investigation it is intended to study the influence of experimentally produced talar fractures on the vascular supply of the talus

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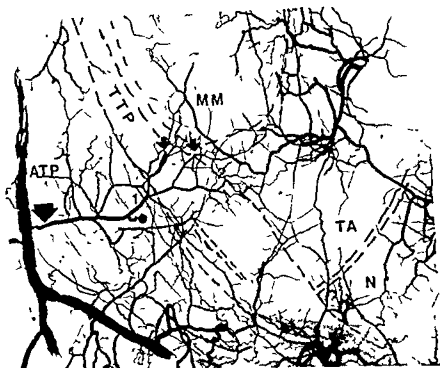


Figure 2 Extraosseous arterial supply of the talus Medial aspect of section 1 (cf. Figure 1) in left foot in 38-year old woman (Spalteholz preparation). MM = medial malleolus, TA = talus, N = navicular bone; TTP = tendo m tibialis posterior; large arrow = arteria canalis tarsi branching off arteria tibialis posterior (ATP); 1 — ramus deltoideus, small arrow to the left = branch penetrating deltoid ligament and entering talus, small arrow to the right = another branch from the ramus deltoideus penetrating to the talus These latter branches correspond to those at small arrows in Figure 4 2 = anastomotic network between the ramus deltoideus and the arteria tibialis anterior and arteria dorsalis pedis Black dot at cut arteria canalis tarsi (cf Figure 4)

15 cm above the level of the malleoli, and the contrast medium, which consisted of one part micropaque mixed with two parts 10 per cent formaldehyde solution (formalin) was injected (it proved to be irrelevant which of the three main arteries was selected for injection) The contrast medium was injected under a constant pressure of 140 mmHg and all vessels from which the contrast medium emerged were tied When leakage no longer was evident, the foot was placed in a bath with 10 per cent formaldehyde solution and the infusion of contrast medium was carried on for 24 hours A constant pressure of 140 mmHg was maintained by a manometer connected to a drip arrangement via a flask, which served as a pressure equilibrator For each foot roughly 40–60 cc contrast medium was used for the initial filling During the 24 hour infusion no more than approximately

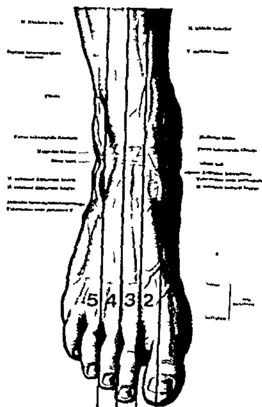


Figure 1 Planes of sagittal sections in feet used for preparation according to the Spalteholtz method Sections numerically indicated (From Lanz & Wachsmuth 1972)

reported that the branches of the main veins followed the main arteries In addition he demonstrated a subarticular collecting vein system beneath the anterior half of the trochlea surface

So far we have been unable to find any references to the lymphatics around the talus

In the present study we have concentrated our interest on the arterial supply

MATERIAL AND METHODS

The material consisted of 12 feet Clinically there was no evidence of vascular disease nor of metabolic disturbances nor of any other illness which might influence the vascular tree The reasons for amputation had been local bone and soft tissue tumours well away from the foot The ages of patients varied from 13 to 63 years with two above 50 years of age, eight between 30 and 50 and two below 20 years of age

The injection of contrast medium in the vascular tree was as a rule carried out 36 to 48 hours following amputation In those instances where it was impossible to carry out the injection within the time mentioned the specimens were stored in a deep freezer When taken out of this the feet remained in room temperature for 48 hours A catheter was introduced into the arteria tibialis posterior at about

Areas of special interest were studied with higher resolution The angiograms were exposed with a Machlett OEG-60 tube at a focus film distance of 15–25 cm 20 kV 10 mA 20–60 seconds on Ilford dental X ray film or Gaevert dentus rapid film The films were developed on glass plates one representing each section This permitted an analysis of the course of vessels as by placing one plate on the top of the other the direction of any particular vessel could easily be followed (see three consecutive sections of one specimen Figures 2 4 and 5)

The whole clearing and examining procedure took approximately 8 weeks for each specimen

RESULTS

Extraosseous supply

There are three main arteries to the foot arteria tibialis posterior, arteria tibialis anterior and arteria peronea

Arteria tibialis posterior Before and after its passage under the medial malleolus branches are given off which anastomose with branches from the arteria tibialis anterior and arteria peronea About 2 cm distal to the medial malleolus the arteria tibialis posterior gives off a branch the arteria canalis tarsi (large *arrow* in Figure 2) which enters the tarsal canal and runs in a posteromedial anterolateral direction Before entering the tarsal canal the arteria canalis tarsi gives off a branch ramus deltoideus (*1 in Figure 2*), running upward on the deltoid ligament dividing into two branches One of them penetrates the deltoid ligament and enters the medial part of the *corpus tali* (*left* small arrow in Figure 2 cf Figure 4) The other branch continues in a forward direction and divides into a number of branches one of which penetrates the talus (right small arrow in Figure 2 cf Figure 4) others form an anastomotic network with vessels from the arteria tibialis anterior and arteria dorsalis pedis

Posteriorly a network is formed by branches from the arteria tibialis posterior and arteria *peronea* From this network branches arise which run to the *processus posterior tali* and enter the bone Other branches run more distally to enter the calcaneus

Arteria tibialis anterior and arteria dorsalis pedis Medially two branches are given off which run down towards the medial malleolus and join in the anastomotic network with the branches from the ramus deltoideus of the arteria *canalis tarsi* Laterally two branches are given off which run down to the lateral *malleolus* The distal lateral branch the arteria tarsea lateralis (AfL *in Figure 3*), originates from the arteria dorsalis pedis It *anastomoses* (*arrows in* Figure 3) with the ramus perforans (RP in Figure 3), *which* originates from the arteria

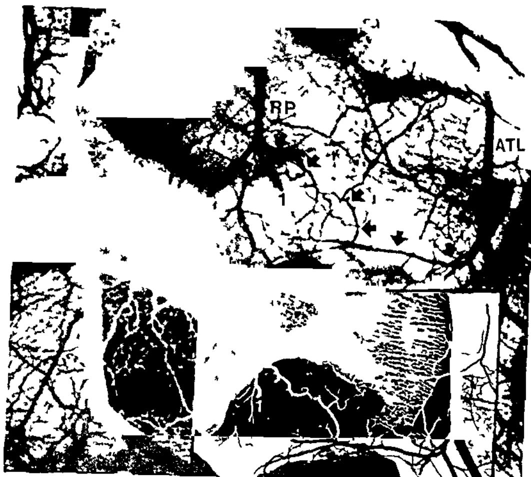


Figure 3 Lateral aspect of right foot in 44 year old man The arteria tarsea lateralis (ATL) gives off an anastomotic branch which connects (arrows) with branches from ramus perforans (RP) of the arteria peronea Arteria sinus tarsi (1) is given off from this anastomosis It is better demonstrated in the inset (section 4 of Figure 1)

5 cc contrast was instilled With this arrangement it became apparent that a good filling of the vascular tree was achieved

Each foot was X rayed in anteroposterior and lateral views Stereograms of the whole foot were made in the lateral view Following X ray the specimens were deep frozen and sectioned in 1 cm thick slices in sagittal planes (Figure 1) (Sections in the frontal planes were made in some cases but no additional information was gained) Each slice was later thawed and X rayed this time by a soft tissue technique utilized for mammary X ray (Senographe CGR) Film focal distance 30 35 cm exposure 25 kV 30 mA 1 5–6 seconds Kodak film (Crystallex®) was used

Following the X ray procedure all slices were treated by the Spalteholtz technique (1914) by which the tissues become translucent and demonstration of the contrast medium filled vessels is facilitated Following the clearing procedure a new series of X rays according to the above standards was taken



Figure 5 Intraosseous vascularization of the talus and interosseous anastomoses Medial aspect of section 3 (cf Figure 1) in left foot in 38 year old woman (same as Figures 2 and 4) Arrow at arteria canalis tarsi C = calcaneus N = navicular bone T = tibia

Intraosseous vascularization

As for the intraosseous vessels they form a richly interconnected system of branches whose main supply is from the arteria canalis tarsi (Figures 4 and 5) The arborization has a direction from the canalis tarsi upward posteriorly and anteriorly i e towards the trochlea and collum tali The main vascular supply of the caput tali is from the arteria sinus tarsi and the aforementioned branches from the arteria dorsalis pedis The interconnection of the intraosseous vessels is distributed in a way which gives no impression of segmental delineation based on the source from which the anastomotic vessels arise

Interosseous anastomoses

The talus has rich vascular connections with the os naviculare and calcaneus by way of the interosseous ligaments and capsules (Figures 4 and 5)

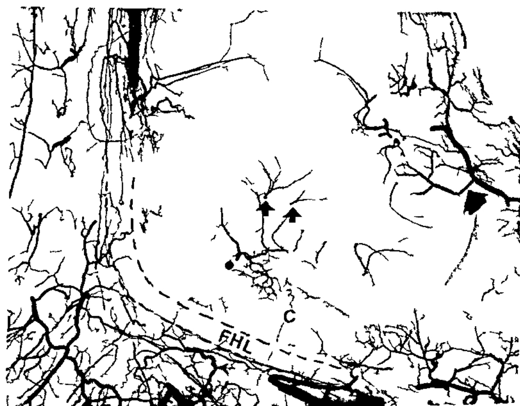


Figure 4 Intraosseous vascularization of the talus and interosseous anastomoses Medial aspect of section 2 (cf Figure 1) in left foot in 38 year old woman (same as Figure 2) The contour of the calcaneus (C) is partly obliterated by the tendon of the flexor hallucis longus (FHL) Large arrow indicates branch from the arteria dorsalis pedis entering the talus Small arrows indicate the continuation of the penetrating branches from the ramus deltoideus (small arrows in Figure 2) Black dot at cut arteria canalis tarsi (cf Figure 2)

peronea and runs through the membrana interossea between the tibia and fibula It is from this anastomosis that the arteria sinus tarsi (1 in Figure 3) arises and then runs in a medial direction straight into the sinus tarsi From the arteria dorsalis pedis branches are given off which run straight down into the neck of the talus through the foramina nutricia (large arrow in Figure 4)

Arteria peronea From this artery the ramus perforans branches off through the membrana interossea as already described Furthermore a number of small vessels branch off in a posterior direction to anastomose with the branches from the arteria tibialis posterior With our technique we have not been able to detect any further branches from this artery of any importance to the talus



F g re ɔ Intraosseous vascular ation of the talus and interosseous anastomoses Me l al aspect of sect on 3 (cf F gure 1) in left foot n 38 year old woman (same as F g ires 2 and 4) Arrow at arteria canal s tars C calcaneus N = nav cular bone T = t b a

Intraosseous vasculari ation

As for the intraosseous vessels they form a richly interconnected system of branches whose main supply is from the arteria canalis tarsi (Figures 4 and 5) The arborization has a direction from the canalis tarsi upward posteriorly and anteriorly i e towards the troch l a and collum tali The main vascular supply of the caput tali is from the arteria sinus tarsi and the aforementioned branches from the arteria dorsalis pedis The interconnection of the intraosseous vessels is distributed in a way which gives no impression of segmental delinea tion based on the source from which the anastomotic vessels arise

Interosseous anastomoses

The talus has rich vascular connections with the os naviculare and calcaneus by way of the interosseous ligaments and capsules (Figures 4 and 5)



Figure 6 Medial aspect of right talo crural joint in 13 year old girl Section 9 (cf Figure 1) Rich anastomotic vascular net work in anterior and posterior ligaments and joint capsule between tibia and talus Marked area enlarged in Figure The darker areas in the tibia and the talus are due to insufficient decalcification

Another feature—not previously described—is the numerous vascular connections between the tibia and the talus These vessels reach the talus by way of the articular capsule and ligaments (Figure 6) In other words there is a direct vascular connection between the tibial and the talar marrow spaces

The angiographic studies with higher resolution have been concentrated to the regions of attachment of the joint capsule to the tibia and the talus respectively The course of the vessels through the capsular insertion into the bone has been demonstrated (Figure 7)

SUMMARY

In this investigation we have limited our studies to the arterial supply of the talus We have been able to confirm all that has been described previously



Figure 7 Angiography with higher resolution of marked area in Figure 6 Vascular connections between the tibia (T) and the talus (TA) via the ligaments and the joint capsule

An additional observation however, is the presence of rich vascular connections between the tibial and the talar marrow spaces by way of the interconnecting capsule and ligaments The talus thus receives a great amount of vessels from many different sources and appears to be in a centre of a large vascular network

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SURGERY FOR ADOLESCENT HALLUX VALGUS

B Helal, S K Gupta & P Gojaseni

Accepted 6 vi 73

Over 130 different operations have been described for adolescent hallux valgus A representative selection is illustrated in the diagrams (Figure 6) Each operation is based on the inventor's concept of the relative importance of various aspects of the pathological anatomy of the deformity (Figure 1)

This bewildering variety of surgical procedures is described, each with its own advocate, so the choice of operation remains a problem Although reviews of certain operative procedures are available (Simmonds & Menelaus 1960, Gibson & Piggott 1962, Wilson 1963, Waugh 1963, Carr & Boyd 1968, on the Mitchell operation) the operation chosen often depends on where the surgeon was trained

Our aim was to present an objective assessment of the operations in current use, thus providing some guide as to the best procedure for the uncommitted surgeon (Figures 2, 3, 4)

A prospective review could have meant performing many unsatisfactory operations so we decided on a purely retrospective review Unfortunately, adequate preoperative data were not always available from the records we collected, so we discarded all the cases with no preoperative X-rays

Experienced, highly skilled, surgical technicians can often turn a sow's ear" of an operation into a "silk purse" of a result; so we assessed not only the end results, but also factors including the technical difficulties and the morbidity of any given procedure

We compared the more popular procedures We sent a questionnaire to 450 orthopaedic surgeons in Britain, (Table 1); 370 replies reflected their interest in the problem Many contained useful and interesting information and we are indebted to them all

In Britain each year, over 2,000 adolescent patients are operated on for hallux valgus, a measure of the importance of the condition; 296 surgeons stated their choice of procedure (Table 2 A)

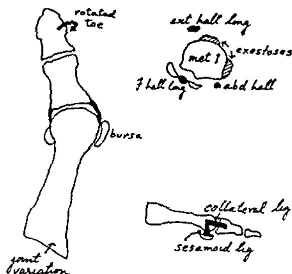


Figure 1 Pathological anatomy of hallux valgus

Left Some of the features seen in A P X rays of the toe and first metatarsal
Upper right Coronal section of head of first metatarsal to show exostoses and displacement of tendons
Lower right Lateral view to show the ligamentous connection between the hallux and first metatarsal

MATERIAL AND METHODS

We began our review in 1960 The procedures chosen for study were the two most popular representatives from each group of operations Table 2B shows the operations chosen and the length of follow up Figures 2 5 show some of the procedures described and some of the complications

Particular note was taken of the weight bearing function of the metatarsal arch as evidenced by metatarsalgia and of callosities under the lateral metatarsal heads An imprint of the foot was taken when there was a normal unoperated side for comparison

The patients ability to wear a standard shoe in complete comfort was also noted

A fresh antero posterior X ray was taken and observations made of

(a) the distance between the first and fifth metatarsal heads measured from their external borders
(b) the gap between the first and second metatarsal heads
(c) the state of bony union where osteotomy had been performed
(d) the degree of subluxation of the first metatarso phalangeal joint
(e) the presence of degenerative changes in the joint
(f) the state of the epiphysis of the first metatarsal
(g) the displacement of the sesamoids and their condition
(h) the degree of rotation of the hallux and any deviation at the interphalangeal joint (Bonney & MacNab 1952)

Table 1 Questionnaire

1. What operations do you do for adolescent hallux valgus?
2. Why did you select the particular procedure?
3. Have you encountered any disadvantages difficulties or complications from your procedure?
4. What on average, is the number of cases you operate on for this condition in a year?
5. What proportion of the cases that you see for adolescent hallux valgus come to surgery?

Table 2 A Operations of choice produced by 296 surgeons in the British Isles

	Operations	No of surgeons
A *Osteotomies*	Butler	4
a) of the proximal phalanx	Unnamed	12
b) of the first metatarsal	Simmonds	20
	Golden	9
i) basal	Rocyn Jones	2
	Stamm	1
	Unnamed	10
(ii) shaft	Wilson	31
	Modified McBride	20
	Hohmann	18
	Mitchell	44
(iii) head and neck	Thomason Mygind	8
	Gibson–Piggott	7
	Cholmeley	1
	Peabody	20
B *Exostectomies* with soft tissue procedures	McBride	34
	Unnamed	10
C *Fusions*		
a) of the first metatarso-phalangeal joint		17
b) of the first metatarsal epiphysis	Ellis	1
D *Arthroplasties*	Keller	17
	Mayo	1
E *Miscellaneous*	Girdlestone	2
	Joplin	7

Table 2 B The review of operations for adolescent hallux valgus (Reviewed in out patients 1966–1968)

Operation	Number of feet	Age in years	Follow up after operation in years			
			0–3	3–6	6–9	9–12
Simmonds	35	14–19	2	4	12	17
Golden	35	14–19	15	17	3	–
Modified McBride	35	14–19	–	8	17	10
Wilson	35	9–19	22	6	7	–
Peabody	35	12–17	14	17	4	–
Mitchell	35	10–18	8	13	14	–
Joplin	35	10–19	20	12	3	–
McBride	35	13–19	21	14	–	–

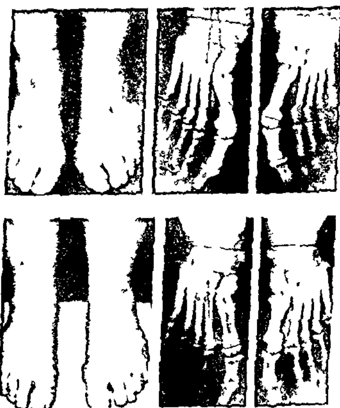


Figure 2 4 The correction of deformity by the Simmonds operation







Figure 2 B The correction of the valgus deformity by the Colden operation

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Operation	Number of feet	Age in years	Follow-up after operation in years			
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Golden	35	14–19	15	17	3	–
Modified McBride	35	14–19	–	8	17	10
Wilson	35	9–19	22	6	7	–
Peabody	35	12–17	14	17	4	–
Mitchell	35	10–18	8	13	14	–
Joplin	35	10–19	20	12	3	–
McBride	35	13–19	21	14	–	–

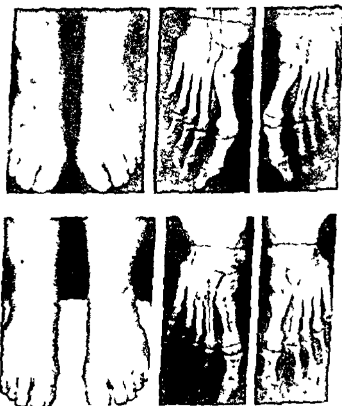


Figure 2 A The correction of deformity by the Simmonds operation



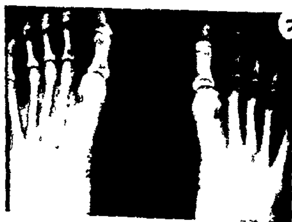




Figure 2 B The correction of the valgus deformity by the Golden operation

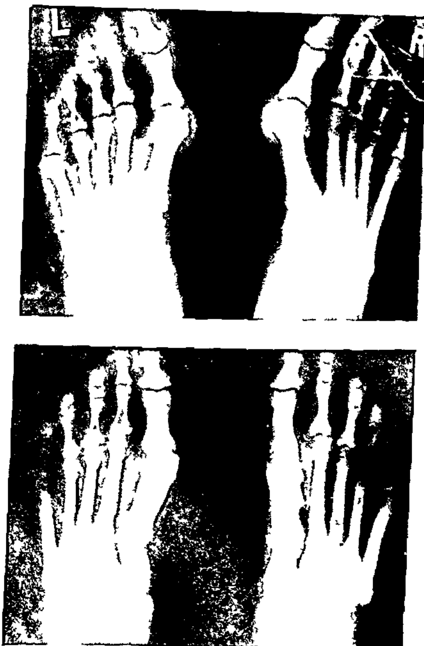


Figure 3 A The correction of deformity following the Wilson operation of the right foot

The patients views regarding the results of the operation were recorded The end result was assessed by us and classified as excellent good or poor The criteria employed are shown in Table 3

Procedures discarded from this review

We collected small numbers of metatarso phalangeal joint fusions excision arthroplasties osteotomies of the base of the proximal phalanx and epiphysiodeses



Figure 3 B The over correction of deformity by the modified McBride operation of the right foot

Table 3 Criteria for classification of the results after operation (after Bonney & McNab)

Results	Amount of hallux* valgus (in degrees)	Intermetatarsal§ angles (in degrees)	Range of movements of the first metatarsophalangeal joint	Symptoms	Function
Excellent	0–20	0–12	Full range		Full
Good	0–30	0–16	Some limitation of dorsiflexion or active plantarflexion	Occasional ache in the metatarsophalangeal joint after use No bunion	Satisfactory
Poor	>30	16	Marked limitation of movements or no movement	Frequent pain in the metatarsophalangeal joint or foot Bunion present	Impaired

* Degrees of hallux valgus is the angle between the axes of the first metatarsal and the proximal phalanx

§ Intermetatarsal angle is the angle between the axes of the first and second metatarsals.







Figure 4 A The correction of deformity in the immediate post operative period and five years after the Peal ody operation



Figure 4 B A case of non union following the Peabody operation



Figure 5 A A case of dorsal tilting of the distal fragment following Wilson operation

of the first metatarsal. We abandoned the search for further cases as the results were much poorer than the other procedures

Epiphysiodesis of the base of the first metatarsal is a rational approach, but most cases present too late for the deformity to be influenced significantly by arresting





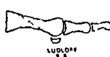
Figure 5 B. The double-oblique osteotomy of the metatarsal by modifying the Wilson operation.









FULD
1919



JUVARA




SILVER
1923

ADD
EHL



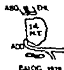
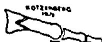

GOEBELL
1927

EHL
ADD











Figure 5 B The double oblique osteotomy of the metatarsal by modifying the Wilson operation

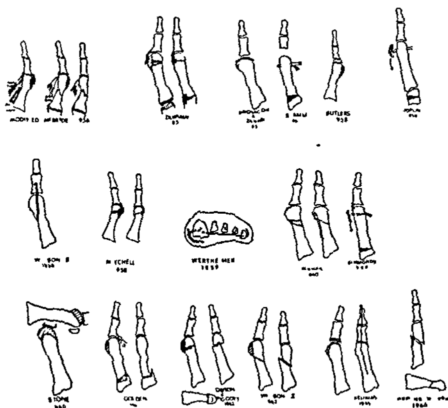


Figure C A selection of the operations described for adolescent hallux valgus

further growth secondary deformities have already occurred at the metatarso phalangeal joint

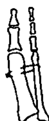
Out of 842 operation records only 378 provided adequate pre-operative data From these we selected 35 of each procedure as being suitable for comparison as this was the largest number of Joplin and Golden *procedures* available We therefore took the 35 cases with the longest follow up from those procedures where larger numbers were available

All patients within seventy *miles* of London were contacted and requested to attend for examination at the *hospital* where they had had their operations

Method

A fresh history was taken including pre- and post-operative symptoms, and compared with the pre-existing notes. Operative methods were recorded and any complications noted

X rays Intermetatarsal *angles* were measured on the pre and post-operative X rays The standard mean intermetatarsal *angle* is 8 9° in the normal adolescent foot and 13° in the morbid group (Hardy & Clapham 1951) with a variation of



LENGGENHAGER

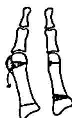
STANLEY & BRECK
1935



G RDLESTONE
1937


PETRI 1940



ROCYN JONES

LOGROSCINO

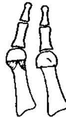
MASSART
1948

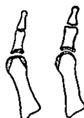
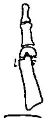
JOPL N
1950

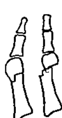
LEL EVRE
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JOPL N
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KOMZA
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BAZY 1952

BONNEY & MACNAB



LENOX BAKER

MOMMSEN

HU BERT

M ZUNO
1956

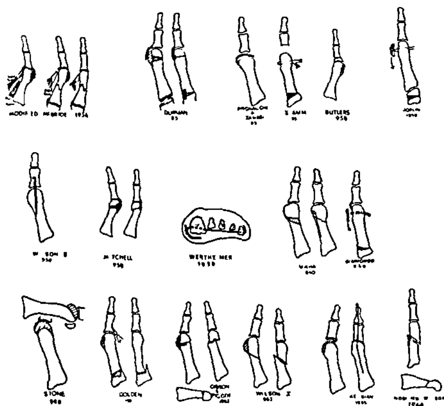


Figure 6 A selection of the operations described for adolescent hallux valgus

further growth secondary deformities have already occurred at the metatarso phalangeal joint

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All patients within seventy miles of London were contacted and requested to attend for examination at the hospital where they had had their operations

Method

A fresh history was taken including pre and post operative symptoms and compared with the pre-existing notes Operative methods were recorded and any complications noted

X rays Intermetatarsal angles were measured on the pre and post-operative X rays. The standard mean intermetatarsal angle is 5.9° in the normal adolescent foot and 13° in the morbid group (Hardy & Clapham 1951) with a variation of

Table 4 Correction of metatarsus primus varus in degrees by osteotomy

Intermetatarsal angle	0 2	2–4	4 6	6–8	8 10	10 12
Simmonds	–	2	5	6	19	3
Golden	1	7	9	4	14	–
Modified McBride	2	9	11	5	8	–
Wilson	–		1	14	16	4

It is interesting to note that those patients operated upon some years before closure of the epiphysis at the base of the first metatarsal exhibited an average increase in the intermetatarsal angle of 3 5° This compares well with the average correction of 9° Correction of metatarsus varus is therefore well maintained

0 17° and 4 27° respectively When considering the modified McBride Wilson Peabody and Mitchell operations the axis of the corrected distal segment of the first metatarsal was employed as the line of reference

Other measurements included the angle of post operative valgus and the length of the first and second metatarsals Hardy & Clapham (1951) recorded the relative first metatarsal protrusion as 2 mm in the normal and 4 mm in the morbid group

For functional assessment the range of dorsiflexion and plantar flexion was measured with a goniometer Note was taken of the ability to squat run and jump The cases were then classified according to Bonney & MacNab s (1952) method

We examined basal metatarsal osteotomies to determine whether with time there was any significant further drift of the metatarsal into varus We found that over an average period of four years between the operation and cessation of growth the degree of increase of varus as measured at the intermetatarsal angle was 0–6° with an average increase of 3 5° This could be compared with the average correction of the varus by osteotomy of 9 5° (Table 4)

We would have liked to include Hohmann s procedure in our analysis but were unable to collect enough cases From the few we investigated it would seem that the results are about the same as those of the Mitchell operation despite the fact that the Hohmann osteotomy is more unstable

Analysis

92 per cent of the patients were female aged from 9 to 19 years in three quarters of the cases the condition was bilateral

160 surgeons answered part 5 of our questionnaire Of these 2 per cent operate on all adolescent valgus great toes 5 per cent avoid operating and 65 per cent operate on about half the number they see 28 per cent of the replies were ambiguous

The number of patients seen by any one surgeon varies greatly in different areas because most general practitioners know in advance that the surgeon is unlikely to recommend operation

280 feet were included in the full analysis Table 5 shows the various procedures the length of follow up and the residual degree of hallux valgus

Table 5 Correction of hallux valgus and its maintenance

Correction of hallux valgus and its maintenance	Angles in degrees	Number of feet operated upon							
		Simmonds	Golden	Modified McBride	Wilson	Peabody	Mitchell	Joplin	McBride
Pre operative	0–10	–		–		–	–	–	–
	10 20	–	–	–		–	–	–	–
	20–30	8	9	8	7	7	10	9	11
	> 30	27	26	27	28	28	25	26	24
Immediate post operative	varus 0–10	–	–	1	–	–	–		2
	valgus 0 10	13	8	13	10	1	5	12	16
	10–20	18	19	18	15	15	14	18	16
	20–30	4	8	3	10	17	16	5	1
	> 30	–	–	–	–	–	–	–	–
0 3 years follow up	0–10	2	3	–	8	–	–		–
	10–20	–	9		10	6	6	3	6
	20–30		3	–	4	3	2	7	8
	> 30				–	5	–	10	2
3 6 years follow up	0–10	1	5	3	1	–	2	–	3
	10–20	3	5	4	5	3	5	1	5
	20–30	–	3	1	–	7	6	5	4
	> 30	–	4	–	–	7	–	6	2
6 9 years follow up	0–10	4	–	7	1	–	1	–	–
	10–20	6	2	8	6	1	6	–	–
	20-30	2	1	2	–	2	5	1	–
	> 30		–	–	–	1	2	2	–
9 12 years follow up	0–10	6		4		–	–		–
	10–20	9		6	–	–		–	–
	20–30	2	–			–	–		–
	> 30	–		–		–		–	–

Inference – Corrections which depend on a *soft* tissue element are not well maintained and recurrences of deformity occur within three years of surgery

DISCUSSION

Factors influencing the results—taking account of both objective and subjective findings we believe that the following factors significantly affect the results

Table 4 Correction of metatarsus primus varus in degrees by osteotomy

Intermetatarsal angle	0–2	2–4	4–6	6–8	8–10	10–12
Simmonds	–	2	5	6	19	3
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It is interesting to note that those patients operated upon some years before closure of the epiphysis at the base of the first metatarsal exhibited an average increase in the intermetatarsal angle of 3 5° This compares well with the average correction of 9° Correction of metatarsus varus is therefore well maintained

0–17° and 4–27° respectively When considering the modified McBride, Wilson Peabody and Mitchell operations, the axis of the corrected distal segment of the first metatarsal was employed as the line of reference

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280 feet were included in the full analysis Table 5 shows the various procedures the length of follow up and the residual degree of hallux valgus

Table 6 *The measurement of the relative first and second metatarsal protrusions*

Operations	+3 mm	+2 mm	+1 mm	0 mm	−1 mm	−2 mm	−3 mm	−4 mm	−5 mm	−6 mm
Simmonds	12	18	5							
Golden	2	7	8	10	5	2	1			
Modified McBride			14	13	8					
Wilson				1	4	13	7	6	3	1
Peabody				2	6	11	9	4	2	
Mitchell			1	3	15	14	2			
McBride			20	12	3					
Joplin				19	14	3				

(b) *Interference with the joint capsule and ligament* Procedures in which the joint was opened or the capsule tightened produced more joint stiffness

(c) *Procedures which increase the bone length* These cause relative increase in soft tissue tension and so reduce joint mobility (Table 6 Figure 2 A) Although we were unable to demonstrate the fact in our patients increased tension across a joint could, theoretically cause or accelerate degenerative changes

3 *The width of the forefoot*

Narrowing of the forefoot rather than a straight great toe was the most valued asset to the female after the absence of discomfort and the presence of mobility (Table 7)

Table 7 *Narrowing of the forefoot after operation*

	0–4 mm	4–8 mm	8–12 mm	12–16 mm	16–20 mm
Simmonds	3	8	14	10	—
Golden	7	19	7	2	—
Modified McBride		6	17	10	2
Wilson	3	6	19	6	1
Peabody	4	15	13	3	—
Mitchell	4	14	15	2	—
Joplin	31	4	—	—	—
McBride	23	9		—	—

1 The technical difficulty of the procedure

2 The amount of mobility in dorsiflexion at the first metatarso-phalangeal joint, for this is most important in squatting (the most severe test), tiptoeing and varying the height of a shoe heel The mobility is affected by these factors:

(a) The degree of soft tissue dissection with its influence on the degree of post-operative fibrosis and so, on the suppleness of the soft tissues

(b) Interference with the joint capsule and ligament

(c) The relative length of bony to soft tissue structure influencing the soft tissue tension

3 The width of the forefoot at the level of the metatarsal heads Subjectively this was very much more important than the degree of valgus at the metatarso-phalangeal joint

4 The ability of the first metatarsal head to take its due share of weight

5 The stability of the procedure with regard to maintaining correction

1 *The technical difficulty of the procedure*

Approximately half the procedures were performed by junior surgeons, usually of registrar status The morbidity in the technically simple procedures was not significantly influenced by the experience of the surgeons In the more technically difficult procedures the overall morbidity was higher and was disproportionately high when performed by less experienced surgeons

2 *Amount of mobility*

The range of dorsiflexion at the first metatarso-phalangeal joint was very much more important than the range of flexion It would seem that a significant degree of flexor power is important only to those engaged in athletic activities

(a) *The extent of the soft tissue dissection* In the immediate post operative period, the more the soft tissue dissection, the greater was the discomfort (as determined by the analgesic requirements), there was also delay in wound healing, a higher incidence of superficial infection and a proportionate (often significant) loss of mobility with impaired function

Table 9 Patients assessment of results

Operations	Satisfied	Not satisfied
Simmonds	28	7
Golden	29	6
Modified McBride	22	13
Wilson	32	3
Peabody	27	8
Mitchell	30	5
Joplin	21	14
McBride	16	19

Table 10 Overall results after operation

Operation	Excellent		Good		Poor	
	No of feet	%	No of feet	%	No of feet	%
Simmonds	10	29	18	51	7	20
Golden	15	48	15	43	5	14
Modified McBride	12	34	8	23	15	43
Wilson	18	51	15	43	2	6
Peabody	12	34	11	32	12	34
Mitchell	16	46	12	34	7	20
Joplin	4	11	17	49	14	40
McBride	5	14	11	32	19	54

RESULTS

Tables 9 and 10 summarize the results

Complications

These were few and suggest an overall high standard of surgery Predictably there was a higher incidence of superficial infection following wound haematoma and adhesions in those procedures involving a good deal of soft tissue dissection—notably the McBride, modified McBride and Joplin operations These all settled rapidly on simple measures Other complications included non union or displacement of the osteotomy (Figure 4 B, 5 A) over correction of the deformity was fortunately rare (Figure 3 B), as this was extremely difficult to deal with and finally relapse of the deformity as summarized in Table 5

Table 8 The most important factors influencing the results

		Technical difficulty	Soft tissue trauma	Mobility of metatarso phalangeal joint	Narrowing of forefoot	Relaxation of soft tissue	Stability of correction	Weight bearing function of metatarsal arch	Totals
Basal osteotomy	Simmonds	2	3	4	2	5	1	2	19
	Golden	5	3	1	3	3	1	2	18
Shaft osteotomy	McBride	5	5	5	1	3	3	1	23
	Wilson	1	1	1	2	1	2	2	10
Neck osteotomy	Peabody	3	3	3	2	2	3	3	19
	Mitchell	3	3	3	2	3	3	3	20
Soft tissue procedures	McBride	5	5	5	3	4	4	2	28
	Joplin	5	5	5	4	5	5	2	31

A point system has been devised the lowest score indicates the best situation

Basis for point system

Technical difficulty – two factors tourniquet time and personal knowledge of the procedures

Soft tissue trauma – personal knowledge of the dissection required

Mobility of MP joint – average figures for total mobility This was related to relaxation of soft tissues and degree of scarring of capsule and adjacent tissues

Narrowing forefoot average measurements pre and post operatively

Relaxation of soft tissue – based on measurements of relative first and second metatarsal protrusion

Stability of correction based on incidence of recurrence of valgus and redisplacement of osteotomies

Weight bearing function – based on incidence of subsequent metatarsalgia and *presence of callosities under the lateral metatarsal heads*

4 *Weightbearing by the first metatarsal head*

This is of particular importance in relation to osteotomies for if there is any dorsal shift of the first metatarsal, pressure is shifted onto the lateral metatarsals with subsequent metatarsalgia Thus the problem is exchanged for another which may be even more disabling

5 *The stability of the procedure*

It is important to maintain the advantages gained by surgery and prevent relapse of the deformity A point system was devised to compare all the above factors in relation to each procedure (Table 8)

The foot is bandaged with the great toe in a few degrees of varus. After two weeks the sutures are removed and a below knee walking plaster applied for a further four weeks.

We analysed a further 57 feet (42 patients) treated in this way, 52 feet were excellent and the other 5 good according to the criteria already mentioned (Table 3).

CONCLUSIONS

Our study suggested certain principles for a successful operation for adolescent hallux valgus. The procedure is best carried out in the early teens rather than later. Interference with the metatarso phalangeal joint should be avoided. This joint apart from being valgus, is usually painless and fully mobile prior to operation. It is unjustifiable to destroy such a joint by arthrodesis or artroplasty, particularly in the growing foot.

Attempts to align the hallux on the metatarsal will alter the congruity of the metatarso-phalangeal joint surfaces and may give rise to stiffness, pain and possibly degeneration in later life. Soft tissue dissection interfering with the capsule or para articular tissues will result in scarring and stiffness. Procedures which tighten the soft tissues by producing relative lengthening of the metatarsal will also produce stiffness of the metatarso-phalangeal joint. The adage that the more complex the procedure the worse the result seems to hold true for this type of surgery. [illegible]
good function is [illegible]
operations that narrow the width of the forefoot please the patient.

SUMMARY

Numerous operations for the correction of adolescent hallux valgus have been described. A comparison of the most popular surgical procedures currently practised in Britain has been carried out. The factors influencing the success or failure of these operations are discussed.

A consistently reliable procedure was found to be the metatarsal shaft osteotomy described by Wilson. Its merits are that it is technically simple, produces minimal soft tissue trauma and results in a good correction of the deformity. It narrows the forefoot, relaxes the soft tissues and retains excellent mobility at the metatarso-phalangeal joint.

*Table 11 Further 60 Wilson's operation analysed**

Types	Number	Length of follow up in years	Age in years	Result		
				Excellent	Good	Poor
Adolescent Hallux Valgus	36	1–9	13–19	22 (61%)	9 (25%)	5 (14%)
Adolescent Hallux Valgus operated on at a later age	24	1–8	20–35	9 (38%)	13 (54%)	2 (8%)

* These cases were operated on at the Royal National Orthopaedic Hospital

The Wilson shaft osteotomy

This operation had the best results, consequently we studied a further 60 cases Table 11 shows the relevant findings The poor results were mainly due to metatarsalgia associated with a dorsal shift or tilt of the first metatarsal head

The chief technical faults were that the osteotomy had been cut at the wrong angle, or that it had not been sufficiently displaced Too little displacement is easy to avoid, the surgeon merely has to make sure that he has divided the lateral periosteum The angle of osteotomy is also critical and we saw a number of examples where it was too transverse or too oblique

Often the metatarsal head had been allowed to tilt dorsally or to displace dorsally To avoid this, one of us (B H) devised a modification of Wilson's technique (Figures 5 A, 5 B, 6)

The osteotomy is performed with an oscillating saw and commences at 45° to the main axis of the shaft of the metatarsal, just proximal to the exostosis, which, if large, is removed The saw is also slanted so that the bone is sectioned obliquely plantarwise and proximally from the dorsum (Figure 6) This double oblique osteotomy prevents the dorsal tilting of the distal fragment, and also increases the area of contact at the bone ends, thus enhancing sound union After displacement of the distal fragment laterally the medial projecting spike of the proximal fragment is shaved off to narrow the forefoot further

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Dorsal displacement of the metatarsal head may occur with subsequent stress on the lateral metatarsals producing metatarsalgia This can be completely overcome by adding a second obliquity to the osteotomy

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FRACTURES OF THE NECK OF THE TALUS

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The fracture of the neck of the talus is the commonest major injury of this bone and it is generally regarded as a serious traumatic lesion of the ankle (Coltart 1952, Pennal 1963, Mindell et al 1963) This is mainly because of the various and severe complications which usually follow this fracture whenever it is associated with subtalar subluxation or dislocation of the body of the talus (McKeever 1963, Kenwright & Taylor 1970, Hawkins 1970)

The management of this fracture and of the complications is difficult It has been improved, however, since Anderson (1919) described the mechanism of injury and by recognition of the importance of early reduction (Miller & Baker 1939, Boyd & Knight 1942) Nevertheless even today the results of treatment of this fracture as a whole are generally poor (Pennal 1963, Mindell et al 1963, Hawkins 1970) This is mostly due to frequent complications such as avascular necrosis of the displaced talar body, osteoarthritis of the subtalar and/or the ankle joint and sepsis Many of these injuries are compound or become open because of sloughing of the skin stretched over the dislocated body of the talus

Classification

The fractures of the neck of the talus are generally divided into three groups of different severity and prognosis, i e the fractures with minimal or no displacement, the displaced ones associated with subluxation of the posterior subtalar joint and the fractures in which the body of the talus is completely dislocated from both the ankle and subtalar joints (*Coltart 1952, Watson-Jones 1960, Pennal 1963, Hawkins 1970*) This widely used classification is easy to make from the

Table 1 Types in twenty fractures of the neck of the talus

Group	Type of injury	No of cases
1	Fracture of the neck with minimal or no displacement and without dislocation	4
2	Fracture of the neck with displacement and subtalar subluxation or dislocation	9
3	Fracture of the neck with total dislocation of the body of the talus	6
4	Fracture of the neck with dislocation of the head of the talus	1
	Total	20

radiographic appearance, it suggests the severity of the injury in each group and indicates the line of the initial treatment and the prognosis

MATERIAL AND METHODS

This is a series of 20 fractures of the neck of the talus treated from 1951 to 1970 Fractures involving the body of the talus and minor injuries such as flakes from the neck of the bone are not included in the series



Figure 1 Lateral radiograph showing the unusual compound fracture of the neck of the talus with superior displacement of the head and dislocation of the astragaloscaphoid joint before reduction The injury became infected

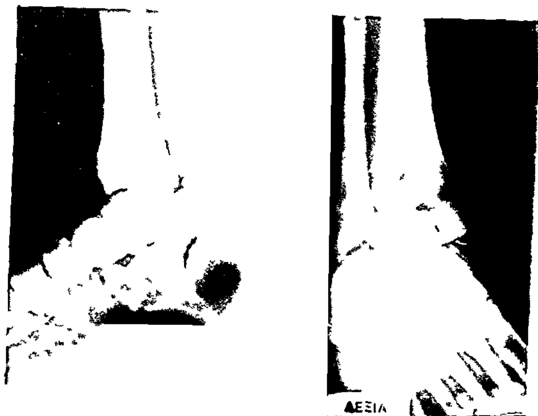


Figure 2 a Lateral and antero posterior radiographs showing an unusual fracture dislocation of group 3 The body of the talus is upside down Note the associated fracture of the medial malleolus

Age and sex The age of the patients ranged from 9 to 59 years with an average age of 32 years Sixteen patients were male and 4 female

Cause and mechanism of injury Thirteen of the patients were involved in motor cycle or car accidents and 7 had a fall from a height It was difficult to determine the mechanism of injury in most of our patients Many of those involved in car accidents were drivers or front seat passengers and it is presumed that a dorsi flexion force was the cause of the injury Two of our 6 patients with total dis location of the body of the talus had an oblique or vertical fracture of the medial malleolus in association with the fracture of the neck of the talus This possibly indicates that external rotation and/or adduction forces in addition to hyperex tension are involved in the mechanics of the injury

Type of injury The vertical fracture of the neck of the talus was usually as sociated with either subluxation of the subtalar joint or complete dislocation of the talar body (Table 1) There was one case in this series with a compound fracture through the anterior portion of the neck in which the head of the talus was displaced superiorly so that there was a dislocation of the astragalo scaphoidal joint the body of talus retaining its normal position in the ankle and the subtalar joint (Figure 1) This very unusual type of injury could not be classified in any



Figure 2 b The same case at the end of open reduction and internal fixation of the fractures

of the three groups in which the fractures of the neck of the talus are generally divided

In group 3 injuries there was one case of a fracture of the neck with a unique degree and direction of rotation of the dislocated body of the talus (Figure 2 a) In this case the talar body dislocated from both the ankle and the subtalar joints was rotated through 180 degrees on its transverse horizontal axis so that it was lying upside down This case has been reported as an extremely unusual type of fracture dislocation (Pantazopoulos et al 1972)

Apart from the open fracture with the unusual dislocation of the head of the talus in group 4 One fracture dislocation in group 3 was a compound injury while a second one became open and infected because of sloughing of the skin stretched over the displaced body of the talus

Treatment

The group 1 fractures were treated by immobilisation in a non weightbearing below knee plaster for 8 12 weeks at which time there was evidence of union in every case

In 5 out of the 9 fractures of group 2 reduction was accomplished by closed methods The foot was immobilised for the first 6–8 weeks in plantar flexion so that satisfactory reduction of both the fracture and the dislocation were obtained and in eversion whenever there was medial subtalar subluxation Then the plaster was changed and the foot immobilised in less flexion or neutral position until there



Figure 2 c Eight weeks later at the time of removal of the Kirschner wire and change of plaster Avascular necrosis of the body of the talus is obvious

was radiographic evidence of union usually for another 6–8 weeks Protected weightbearing was then allowed Open reduction was carried out in the remaining 4 cases of this group after attempted closed manipulation had failed A medial approach was used and the fracture was usually fixed by a Kirschner wire Post operatively the leg was immobilised in a below knee plaster until the fracture was united usually for 12–14 weeks In the case of avascular necrosis of the body of the talus a usual complication in this group of fractures, plaster immobilisation was prolonged and so was the non weightbearing period which varied from 5 12 months from the time of injury

In most of group 3 fracture dislocations closed reduction was attempted as an emergency without success Open reduction therefore was carried out for all the patients of this group and for the single case of group 4, apart from one case for which astragalectomy was performed This was the patient whose admission was delayed and in whom sloughing of the skin occurred over the displaced talar body and sepsis developed A tibio calcaneal fusion was carried out later As a routine a Steinmann pin was inserted transversely through the calcaneum to facilitate closed reduction Then the pin was left in place since it was found to be a great help in distracting the os calcis from the tibia during open reduction As in group 2 the medial approach was used and the fracture was usually fixed by a Kirschner wire (Figure 2 b) Plaster immobilisation was continued for various periods of time after union of the fracture while weightbearing was not allowed for 5–14 months since in all cases in this group avascular necrosis of the body of the talus developed

Table 2 Complications for each group of fractures

Group	No of cases	Sepsis	Avascular necrosis	Osteo arthritis
1	4	–	–	1
2	9	–	4	6*
3	6	1	5§	4
4	1	1	–	1
Totals	20	2	9	12

Includes the four (4) cases with avascular necrosis which also developed osteo arthritis

§ Excludes only one patient of group 3 in whom infection developed and the body of the talus was excised

RESULTS

All the patients were reviewed by us and evaluated on the basis of pain presence of limp, and range of movement in the ankle and subtalar joint according to Hawkins' (1970) numerical rating

The follow up varies from one and a half to nine years The complications for each type of fracture are shown in Table 2 and the clinical results in Table 3

Complications

All the fractures of group 1 had an excellent or good result Complications did not appear apart from slight osteoarthritis of the subtalar joint in one patient aged 54 years

In the majority of group 2 injuries (6 out of 9) and in all the cases of group 3 serious complications developed resulting as a rule in a fair or poor outcome

Table 3 Clinical results for each group of fractures

Group	No of cases	Excellent	Good	Fair	Poor
1	4	3	1	–	–
2	9	2	2	2	3
3	6		1	2	3
4	1		–	–	1
Totals	20	5	4	4	7

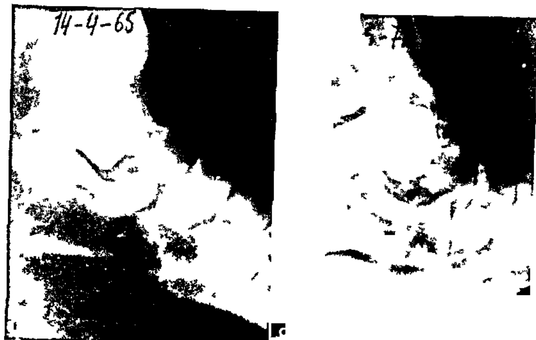


Figure 3 a Lateral radiograph showing advanced replacement process of the bone of the talar body two years following avascular necrosis
Figure 3 b Six years later Collapse of the body of the talus has occurred and osteoarthritis developed

Avascular necrosis occurred in 4 out of the 9 group 2 fractures and in all of group 3 All these patients developed osteoarthritis in the subtalar and/or the ankle joint with collapse of the talar body in many of them (Figure 3) regardless of the length of time of protection from weight bearing being from five months to more than one year The only exception so far is one case of group 3 in which osteoarthritis could still develop since the period from the time of injury is only one and a half years

Osteoarthritis developed in two more cases of group 2 In one of them the dislocation of the subtalar joint had been overlooked

Sepsis occurred in 2 out of the 7 cases of groups 3 and 4 One of these was the closed injury with delayed admission and sloughing of the skin and the other was the compound unusual fracture dislocation of group 4

Clinical results

Three of the 4 patients of group 1 had an excellent result while the 4th had a good outcome since only slight osteoarthritis of the subtalar joint developed

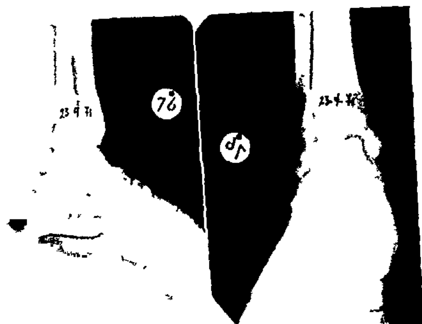


Figure 4 Lateral and antero posterior radiographs showing only slight osteoarthritis of the subtalar joint seven years after avascular necrosis of the body of the talus following a neck fracture-dislocation The repair process of the dead bone of the body has almost been completed

Of the 9 patients of group 2, 5 had only a fair or poor outcome as a result of avascular necrosis in 3 of them and osteoarthritis in the other two The fourth patient with avascular necrosis in this group had a good result Only slight osteoarthritis of the subtalar joint had developed seven years after injury (Figure 4)

Five out of the 6 patients of group 3 had a fair or poor result because of sepsis in one case and avascular necrosis with osteoarthritis in the other four The 6th case of this group was classified as a good result, although osteoarthritis could still appear

The unusual type of injury of group 4 for which eventually a pantalar arthrodesis was carried out is classified as a poor result according to the rating used

DISCUSSION

The fractures of the neck of the talus as a whole are serious injuries and of poor prognosis The severity of the injury, however, and the

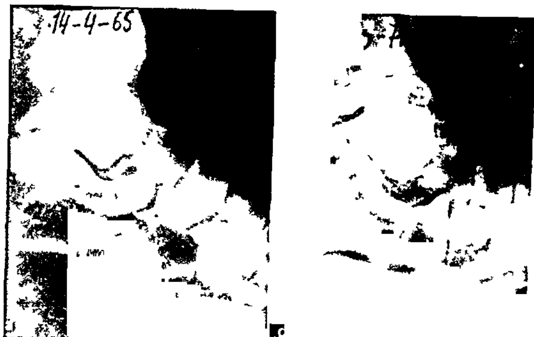


Figure 3 a Lateral radiograph showing advanced replacement process of the bone of the talar body two years following avascular necrosis
Figure 3 b Six years later Collapse of the body of the talus has occurred and osteo arthritis developed

Avascular necrosis occurred in 4 out of the 9 group 2 fractures and in all of group 3 All these patients developed osteoarthritis in the sub talar and/or the ankle joint with collapse of the talar body in many of them (Figure 3) regardless of the length of time of protection from weight-bearing, being from five months to more than one year The only exception so far is one case of group 3 in which osteoarthritis could still develop since the period from the time of injury is only one and a half years

Osteoarthritis developed in two more cases of group 2 In one of them the dislocation of the subtalar joint had been overlooked

Sepsis occurred in 2 out of the 7 cases of groups 3 and 4 One of these was the closed injury with delayed admission and sloughing of the skin and the other was the compound unusual fracture dislocation of group 4

Clinical results

Three of the 4 patients of group 1 had an excellent result while the 4th had a good outcome, since only slight osteoarthritis of the subtalar joint developed

cess of the dead bone and talectomy with or without tibio calcaneal arthrodesis have not been proved worth considering (Pennal 1963, Kenwright & Taylor 1970 Hawkins 1970) On the other hand osteo arthritis usually develops in the subtalar joint in which case only arthrodesis of this joint is required Even when fusion of the ankle would be demanded the chances of successful arthrodesis are much higher when the talar body has been left in place and replaced by living bone

Avascular necrosis is better managed by first allowing the fracture to heal in a non weightbearing plaster after it has been accurately reduced and fixed by a Kirschner wire Non union did not occur in our cases with avascular necrosis and according to other reported series it is an exceptionally rare complication although some delay in healing could occur (Pennal 1963 Mindell et al 1963 Kenwright & Taylor 1970 Hawkins 1970) In this case immobilisation in plaster should be maintained until radiographical union Once the fracture has united the question arises as to the period of time during which protection from weightbearing is required This period varied from several months to more than a year in 7 of our 9 cases with avascular necrosis but prolonged non weightbearing did not always prevent collapse of the talar body On the other hand in the remaining 2 cases collapse did not occur in spite of initiation of weightbearing soon after the healing of the fracture This has also been found by many other authors (Mindell et al 1963 Hawkins 1970) For these reasons and the fact that no surgery has been proved to speed up the prolonged replacement process of the avascular body of the talus or to prevent its collapse it seems reasonable that progressive weightbearing could be allowed once bony union of the fracture of the neck of the talus has been achieved

SUMMARY

This is a report of 20 fractures of the neck of the talus followed up from one and a half to nine years

They are classified in the 3 usually described groups to which a further group has been added to include one case of a fracture with an unusual dislocation of the head of the talus

Their initial treatment and the final results are mentioned and discussed In group 1 fractures a very good result is the expected outcome The prognosis of group 2 fractures is unfavourable while for those in

incidence of complications vary greatly with the type of fracture In a group 1 fracture serious complications do not occur and the results of their treatment are very good (Coltart 1952, Pennal 1963, Kenwright & Taylor 1970, Hawkins 1970) In group 2 fractures the prognosis is unfavourable while in those of group 3 it is very poor indeed, because of the development of frequent and serious complications (Coltart 1952, Pennal 1963, Mindell et al 1963, Hawkins 1970)

The occurrence of avascular necrosis of the body of the talus predominates in the prognosis of this injury Therefore the management of the avascular necrosis and the primary treatment are the main problems in the therapy of these fracture-dislocations

Closed or the usually required open reduction should be done on admission for compound and closed injuries alike to prevent skin necrosis and sepsis Accurate reduction and fixation of the unstable fractures by a Kirschner wire is of importance (McKeever 1963, Kenwright & Taylor 1970) The medial approach is usually recommended through which screwing of the commonly fractured medial malleolus is also performed (Coltart 1952, Pennal 1963, Hawkins 1970) When it is not fractured, osteotomy of the malleolus is probably preferable to the release of the deltoid ligament This would better facilitate the reduction of group 3 fractures and it interferes less with the arterial branch of the deltoid ligament This artery is described as one of the three main sources of blood supply to the body of the talus and it has many anastomoses with the other arteries contributing to the blood supply of the talus (Mulfinger & Trueta 1970)

Avascular necrosis of the body of the talus can be easily identified 6 8 weeks after the injury because the body of the talus unaffected by osteoporosis shows up apparent increased density at that time (Figure 2 c) True increase in the density of the avascular talar body is clearly demonstrated later and for many years following the injury This is an absolute increased density, however, and it represents the healing process of the bone which has been dead This can only occur while the bone is being revascularised As new bone is being laid down on the surface of the necrotic trabeculae which have not yet been absorbed completely, increased density appears on the radiographs, as with revascularisation of other bones (Harris & Bobechko 1960, Catto 1965 a, 1965 b)

Opinions vary greatly as to the proper management of avascular necrosis of the body of the talus Operative methods of treatment such as bone grafting or subtalar fusion to encourage the replacement pro

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Directorate of Employment Accident Insurance & Department of Orthopaedic Surgery U Rigshospitalet Copenhagen Denmark

FRACTURE OF THE TALUS

A Study of its Genesis and Morphology Based Upon Cases with Associated Ankle Fracture

OTTO SNEPPEN & OLE BUHL

Accepted 30 x 73

From the literature it seems evident that to a great extent fracture of the talus has been looked upon as an isolated phenomenon rather than as a link in a more comprehensive injury involving also the neighbouring structures in particular the ankle joint, subtalar joint, and appurtenant ligaments

However the talus is well protected from direct outer forces, and the traumatizing forces are transmitted mainly *via* the adjacent structures There is reason to assume, therefore, that injury of the talus is often just one link in a more comprehensive injury As in the case of ankle fractures increased knowledge about the damage to ligaments and joints associated with talar fracture will no doubt create improved possibilities of rational treatment

The present study is based on the fact that forces which act upon the talus and produce fracture of this bone affect also the ankle joint which occasionally is fractured at the same time As far as the ankle fracture is concerned we already have an essentially sufficient and genetically well founded classification system (Lauge Hansen 1942, Bæk Kristensen 1949 Dinstl & Spangler 1963, Solonen & Lauttamus 1965) In cases of simultaneous ankle and talus fracture, therefore, the pathological movement of the foot at the moment of the accident is known and can be related to the morphology of the talus fracture

In the present investigation we have considered the injury of the talus as an integral part of a more comprehensive regional injury On this basis we succeeded in elucidating some hitherto unknown factors in its genesis

group 3 it is very poor because of the development of serious complications which are difficult to treat

Provided a satisfactory primary treatment of these fracture-dislocations has been carried out, the outcome almost entirely depends on the appearance of avascular necrosis of the body of the talus The treatment of this complication is discussed

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In this respect the material accords with other materials of talar fractures Pennal 1963 Bircher 1965), whereas it differs completely from other materials of ankle fractures (Klossner 1962 Solonen & Lauttamus 1968)

RESULTS

Table 2 gives the occurrence of talar injury in the various types of ankle fracture It will be seen that supination trauma, in particular, seems to have entailed injury of the talus, the frequency of ankle fractures of the supination type being far higher than in the material as a whole ($P < 0\ 001$) Pronation was next in order of frequency in relation to talus injury, whereas external rotation trauma on a supinated or pronated foot was relatively uncommon ($P < 0\ 01$)

Table 2 Relationship between type of ankle fracture and occurrence of talar fracture and/or subtalar dislocation

Type of ankle fracture	Number of ankle fractures*	Occurrence of talar fracture and/or subtalar dislocation
Supination	295	15 (5 1 %)
Pronation	344	5 (1 5 %)
Supination external rotation	1326	3 (0 2 %)
Pronation external rotation	393	2 (0 5 %)
Irregular	98	1 (1 0 %)
Total	2456	26 (1 1 %)

* [illegible] pronation 14 % supination external rotation 54 % pronation external rotation 16 %, and irregular 4 %

In Table 3 the site of the talar injury is compared to the type of ankle fracture In this respect it is remarkable that fractures of the neck were relatively common, since generally these fractures are said to result from dorsiflexion trauma

If the number of fractures affecting the neck of the talus (Table 3) are related to the number of ankle fractures (Table 2), the following percentage may be seen in the various genetic types supination 2 7, pronation 0 9 supination-external rotation 0 2, pronation external rotation 0 Thus, the occurrence of neck fractures following supination

MATERIAL

The material is partly from the Directorate of Employment Accident Insurance and partly from Dept U of Orthopaedic Surgery, Rigshospitalet Copenhagen The case records including the X ray reports representing this material were perused by the authors

During the period 1960–1966 a total of 1 806 ankle fractures were reported to the Directorate of Employment Accident Insurance Among these cases 20 (1 per cent) had simultaneously sustained talar fractures

This material is representative of the adult population of working age except that it shows a marked male preponderance since normally housewives are not covered by this insurance

At Dept U of Orthopaedic Surgery, Rigshospitalet 600 cases of ankle fractures were treated during the period 1964–1972 Six (1 per cent) were associated with simultaneously sustained talar fractures

The material from Rigshospitalet is not entirely representative as the Department admits a number of cases as a rule complicated ones referred from other hospitals However the two materials do not exhibit any difference with respect to the simultaneous occurrence of talar and ankle fractures and they will be considered together in the following report

Cases in which the injury of the talus was merely a shell shaped avulsion fracture at the insertions of ligaments or capsule were not included in the present material seeing that they have nothing in common with other talar fractures as regards either treatment or prognosis

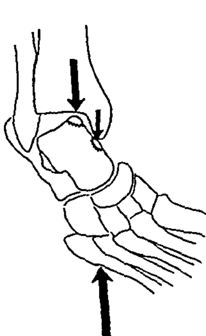
A total of 26 patients had fracture of the talus and ankle of the same limb Twenty five of these ankle fractures could be classified according to a genetic system whereas one was atypical This last mentioned ankle fracture was due to a severe direct trauma and will not be included in the account below

Of the remaining 25 patients 21 were males and 4 females At the time of the accident they ranged in age from 19 to 63 years average 41 years

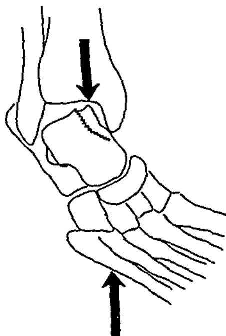
In Table 1 the 25 cases are grouped by type of ankle fracture and nature of trauma Most of the fractures were due to falls or car accidents but jamming of the foot under a heavy weight was another common cause

Table 1 Relationship between type of ankle fracture and genesis of talar trauma

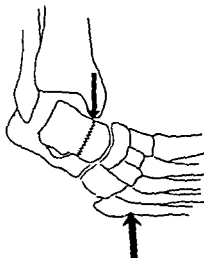
Type of ankle fracture	Fall 1–8 m	Road accident	Heavy weight over foot	Twisting	Total
Supination	7	5	2	1	15
Pronation	2	1	2	0	5
Supination external rotation	1	1	1	0	3
Pronation external rotation	1	1	0	0	2
Total	11	8	5	1	25



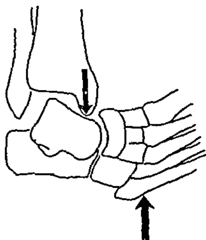
C Compression fracture on the medial surface of the trochlea and/or at its upper medial margin



D Anteposterior fracture of the trochlea



E Fracture of the neck



F Subtalar dislocation

Figure 1

trauma was significantly higher than in the material as a whole ($P < 0.001$)

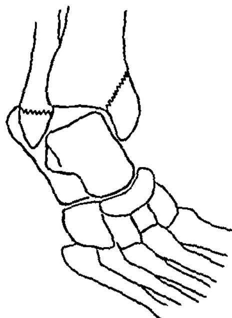
Table 3 Relationship between type of ankle fractures and site of talar injury

Type of ankle fracture	Fracture of neck	Fracture of trochlea		Subtalar dislocation	Total
		medial	lateral		
Supination	8	6	0	1	15
Pronation	3	0	2	0	5
Supination external rotation	2	0	0	1	3
Pronation external rotation	0	0	2	0	2
Total	13	6	4	2	25

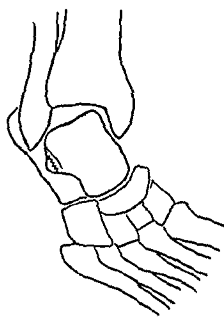
Only *supination injury* of the talus occurred in numbers which permitted further analysis of the group

Figure 1 presents a survey of the supination injuries which occurred in the present 15 cases

Figure 1 A shows an ankle fracture of the supination type The

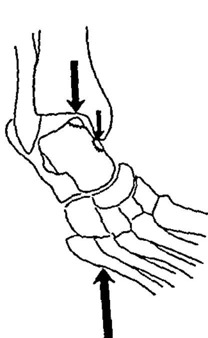


A Ankle fracture of the supination type

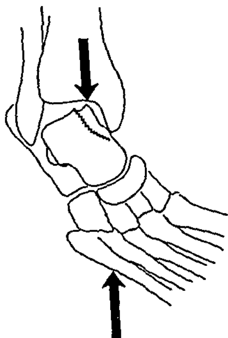


B Avulsion fracture of the insertion of the talofibular ligaments

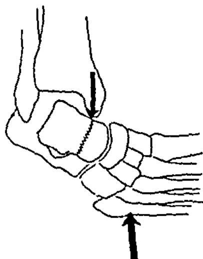
Figure 1 Site of talar injury caused by supination trauma in the present 15 cases



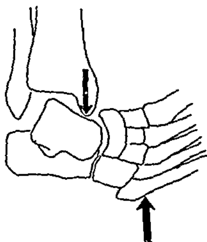
C Compression fracture on the medial surface of the trochlea and/or at its upper medial margin



D Anteposterior fracture of the trochlea



E Fracture of the neck



F Subtalar dislocation

Figure 1



Figure 2 Compression fracture of the medial surface of the trochlea (A) and its upper medial margin (B) In both instances associated ankle fracture of the supination type stage 1

initial injury (stage 1) is an avulsion fracture of the lateral malleolus (Figures 3 and 7) or tearing of the lateral collateral ligament of the ankle or an avulsion fracture at its insertion on the talus and calcaneus (Figure 5) Then follows a fairly sagittal fracture up through the base of the medial malleolus (stage 2) (Figures 4 and 6)

Out of the 15 supination injuries 10 were stage 1, including 5 fractures of the neck, 4 of the trochlea, and one case of subtalar dislocation The remaining 5 cases were stage 2, including 3 fractures of the neck and 2 of the trochlea

Avulsion from the talus at the insertion of the talofibular ligaments (Figures 1 B and 5) had occurred in 2 cases, one of which co-existed with fracture of the neck, the other one with fracture of the trochlea Compression fracture on the medial surface of the trochlea on a level with the tip of the medial malleolus was found in one case, compres-





F gure 3 Anteroposterior shearing fracture of the trochlea before and after reduc t on Assoc ated ankle fracture of the sup nation type stage 1





Figure 4 More oblique shearing fracture of the trochlea involving the subtalar joint with backward displacement of the trochlear fragment Associated ankle fracture of the supination type stage 2

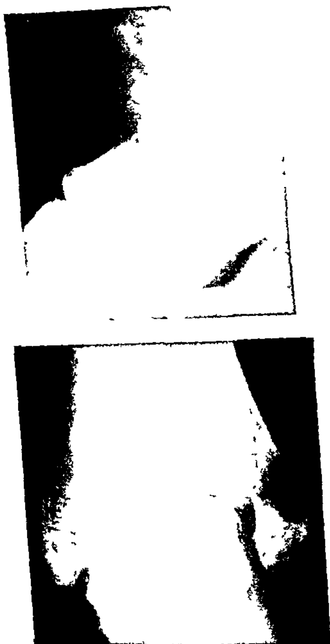


Figure 5. Fracture of the talar neck. Associated ankle fracture of the supination type stage 2 with avulsion fracture at the insertion of the talofibular ligaments



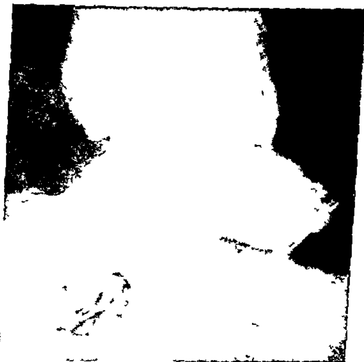


Figure 4 More oblique shearing fracture of the trochlea involving the subtalar joint with backward displacement of the trochlear fragment Associated ankle fracture of the supination type stage 2





Figure 7. Fracture of the talar neck, coursing from the area at the tip of the medial malleolus to the lateral part of the talonavicular joint. Associated ankle fracture of the supination type, stage 1.





Figure 6 I racture of the talar neck Associated ankle fracture of the supinatioi type stage 2

at which fractures of the talar neck occurred Supination, in particular, predisposed to this fracture The quantitative role of supination trauma in the genesis of fracture affecting the talar neck cannot be deduced from the present study

As regards trochlear fractures, it was found in the present material that a medial site (Figures 1 C and D) was typical of the supination trauma whereas a lateral site was typical of pronation or pronation external rotation trauma (Table 3)

These findings are in conformity with the current views on the genesis of trochlear injuries (Kleiger 1963), but at variance with a few other studies (Cameron 1956 Berndt & Harty 1959 Pennal 1963)

SUMMARY AND CONCLUSION

In a material of 2 456 ankle fractures there were 25 cases of associated ankle fracture and talar fracture or subtalar dislocation On the basis of a genetic classification of the ankle fracture, it could be concluded that the position of the foot at the moment of accident was of decisive importance to the frequency at which talar fractures occurred, supination in particular predisposing to fracture of the neck as well as trochlea of the talus

The talar injury which most often occurred in supination, apart from fracture of the neck, was compression fracture or shearing fracture medially in the trochlea

The injury which occurred in pronation was fracture of the talar neck or a compression fracture laterally in the trochlea

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sion fracture at the upper medial margin of the trochlea in one (Figures 1 C and 2) Anteroposterior shearing fracture of the trochlea occurred in 4 cases (Figures 1 D, 3, and 4) In 8 cases there was a fracture of the neck (Figures 1 E, 5, 6, and 7) Lastly, there was one case of subtalar dislocation (Figure 1 F)

DISCUSSION

Experimentally an ankle fracture may be induced by forced dorsiflexion of the pronated foot (Lauge Hansen 1942), but in clinical materials a dorsiflexion type of fracture does not seem to occur (Dinsll & Spangler 1963, Solonen & Lauttamus 1965, 1968) A possible dorsiflexion trauma of the talus, therefore, cannot be detected on the basis of the ankle trauma Consequently, an important field of talar traumatology cannot be elucidated by the present study

Fractures of the neck of the talus are currently believed to be due to dorsiflexion (Kleiger 1948, Watson Jones 1962, Bircher 1965, Jackson & Dickson 1965), although a few cases are on record in which the genesis appears to have been forced plantar flexion (Pennal 1963)

In the present material, however, the fractures of the neck of the talus were particularly common in relation to supination injury of the foot, but were seen also in pronation and supination-external rotation trauma

In some cases these fractures of the talar neck may of course be imagined to be due to simultaneous forced dorsiflexion of the foot But if dorsiflexion alone was the genetic mechanism of fracture of the neck one would expect an equal distribution of the fractures in conformity with the number of ankle fractures (Table 2) However, the fractures of the neck were of an entirely different distribution (Table 3), and this difference cannot be assumed to be due to chance ($P <$ 0 001) Consequently, the theory of dorsiflexion as the sole cause of neck fracture has to be rejected

Instead, there are two possibilities Either the named rotating movements of the foot, in particular supination, may *per se* have caused the talar fracture, or else the fracture has been induced by a simultaneous dorsiflexion trauma which in that case must be particularly apt to occur in supination, more rare in pronation or supination-external rotation

It may be concluded, therefore, that the position of the foot at the moment of the accident was of decisive importance to the frequency

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Department of Neurosurgery and Orthopaedic Surgery Odense Hospital Denmark.

UNSTABLE FRACTURES IN CHILDREN WITH ACUTE, SEVERE BRAIN INJURY

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Accepted 13 ix.73

An ever increasing number of children with multiple injuries are being admitted every year to the departments of neurosurgery, usually after traffic accidents

In severe cases the orthopaedic surgical treatment is complicated by cerebrally elicited increased muscle tonus combined with abnormal mobility patterns Conventional immobilization, e g of femoral fractures in adhesive plaster traction is rendered difficult, or impossible Therefore the question of operative fixation of the fractures has sometimes to be discussed by the neurosurgeon and orthopaedic surgeon This problem does not seem to have been discussed in the literature not even in major textbooks (Blount 1955, Sharrard 1971)

MATERIAL

During the period 1 4 1967 to 31 9 1969 a total of 22 children with brain injuries and unstable fractures of the long bones were admitted to the Department of Neurosurgery Odense Hospital In age they ranged from 3 to 15 years median 8 years 16 of the patients were boys

The site of the fractures was in 14 cases the lower leg—bilateral in one—the femoral shaft in 12 bilateral in 3—the forearm in 3 and the humerus in 2 cases Three of the children died soon after the accident and did not require orthopaedic treatment A 7 year-old boy with *fractures* of both lower legs, treated by immobilization in plaster cast required intermittent ether anaesthesia *gallamine* and chlomethiazole edisylate and respirator therapy through almost 4 *months* because of severe brain stem attacks and constant severe *generalized* increase of tonus and seizures A 13 year-old boy with a *fracture of the lower* leg had over several months considerable increase of tonus which was difficult to manage and as a result the fracture united in a *poor* position although it was immobilized in a plaster cast A boy aged 4 with a fracture of the femoral shaft was treated with adhesive plaster traction Despite energetic *sedative* treatment he had almost constant brain stem attacks and died one week after admission An 8 year-old boy with bilateral fracture of the femoral *shaft will* be described in detail below In the

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Figure 1. A. Right (R) and left (L) femur in the a-p projection at admission. B. Right and left femur after osteosynthesis. C. Right and left femur 2½ year after the accident. The osteosynthesis material has been removed.

other patients the fractures were treated conservatively, all regained consciousness fairly soon and did not present major tonicity problems during the treatment.

The problems relating to operative fixation of extremity fractures in children will now be illustrated by a characteristic case history.

CASE REPORT

A boy, aged 8 years, was admitted as an emergency to a local hospital after a traffic accident. He was in pre-shock, exhibited a dilated left pupil inactive to light and severe generalized increase of tonus. In the right temple there was a large scalp wound. There were also multiple wounds in the face, and several teeth were broken. In addition multiple extremity fractures had been sustained. The patient was treated with intubation, hyperventilation and blood transfusion. To exclude left-sided extracerebral haematoma a cranial terebration was done on the left revealing severe diffuse contusion of the brain.

After the condition had been stabilized, the patient was transferred to the Department of Neurosurgery where he remained deeply unconscious with generalized increase of tonus and an inactive dilated left pupil. He had a severely displaced fracture low on the right forearm, and the hand was oedematous and cyanosed. On both thighs there were large haematomas and considerable angulation caused by fractures of both femoral shafts (Figure 1 a). Lastly, there was an incomplete fracture high on the left tibia.

Exploratory burr holes revealed diffuse cerebral contusion. A tracheostomy was established, and thereafter the orthopaedic surgeons reduced the forearm fracture and applied a plaster cast. The fractures of the lower limbs were treated by adhesive plaster traction. Despite medication with phenobarbitone, chlorpromazine chloride and pethidine chloride, the patient went on exhibiting a violent increase in tonus at the slightest touch. As the condition was unchanged one week after the accident, osteosynthesis of both femoral fractures was done, and they were fixed with double plating (Figure 1 b). The lower leg fracture was stable and was treated in a plaster cast. A few days later the patient was relaxed on unchanged medication and no longer presented any major nursing problems. The first weeks of the course are illustrated in Figure 2.

Slowly the level of consciousness increased, and 3 weeks after the accident the patient started opening his eyes, 6 weeks after he could say a few words, and 10 weeks after he could distinguish colours and write a few figures and words. The fractures had then healed, and the osteosynthesis material was removed.

One year after the accident the boy could walk and run, but in a somewhat ataxic manner, and he quickly tired. Mentally he showed behavioural disturbances characterized by aggressive tendencies. Isotope liquorgraphy and pneumoencephalography disclosed severe communicating obstructive hydrocephalus, so that a right-sided ventriculo-atrial shunt was established (Kjærsgaard Pedersen & Haase 1973). Thereafter he made a rapid mental recovery.

Two and a half years after the accident he was doing normally for his age at school, was playing naturally with his mates, and was, unlike before, good and helpful at home. His gait showed no abnormalities, the lower limbs were of equal length, and mobility in the hip and knee joints was free. Follow-up x-rays showed

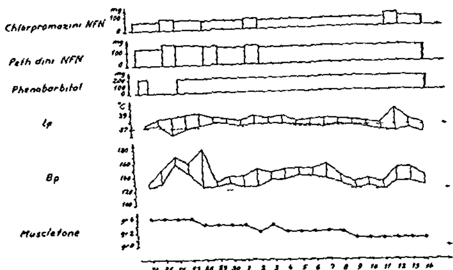


Figure 3 The first 20 days of the course in a 13 year old boy with a severe cranial trauma Note the continuously increased tonus the relatively high blood pressure and the subfebrile temperature despite high doses of sedatives No osteosynthesis

in children There is very seldom indication for osteosynthesis, considering the numerous complications of this treatment (Blount 1955) In a prospective study Barfod & Christensen (1959) found that conservatively treated patients had a shorter treatment period and achieved better results as regards longitudinal growth Accordingly, they too rejected osteosynthesis

The situation is a different one in patients with co-existing severe brain injury deeply unconscious, and with varying degrees of generalized increase in muscle tonus brain stem attacks, or other abnormal patterns In the most severe cases this condition may last for weeks or months (Overgaard et al 1970), caused by disturbances of brain stem function This muscle tonus controlling function is affected by all afferent impulses which increase muscle tonus and intensify abnormal mobility patterns The violent muscle activity, thus induced, entails enormous production of heat *Inter alia* because of autonomous disturbances the patient is unable to give off this heat and rapidly develops hyperthermia This increases the demands on the oxidative metabolism of the brain, further deteriorating the patient's condition Simultaneously with the muscle activity, the systolic blood pressure rises and in patients with severe brain injuries this increases the risk

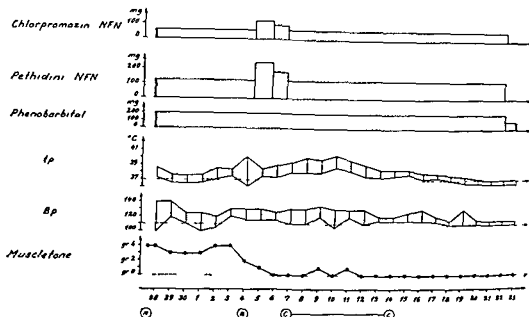


Figure 2 The first 25 days of the course in an 8-year-old boy with severe cranial trauma Treatment at admission to Department of Neurosurgery (A), bilateral femoral osteosynthesis (B), and period of bronchopneumonias and thrombophlebitis in the upper limbs (C—C)

Bp Blood pressure

Tp Temperature

Muscle tone

Grade 0 Normal tonus, normal mobility pattern

Grade 1 Intermittently slightly increased tonus, normal mobility pattern

Grade 2 Intermittently increased tonus and abnormal mobility patterns on rough manipulation

Grade 3 Constantly increased tonus with abnormal mobility patterns elicited by rough manipulation, suction etc

Grade 4 Constantly increased tonus and unprovoked abnormal mobility pattern

perfectly united fractures in both femora, without any signs of angulation (Figure 1 c)

DISCUSSION

Femoral fractures in children without cerebral injury differ in many ways from femoral fractures in adults Union is rapid, non-union extremely rare, and there is a marked tendency to spontaneous correction of deformities (Guldhammer 1963) As a rule, adhesive plaster traction is sufficient to achieve the goal Instability of the fracture and pain at the fracture site seldom pose any problem after one week's treatment Complications are rare Thompson & Mahoney (1951) found only 9 cases of Volkmann's contracture among 1239 femoral fractures

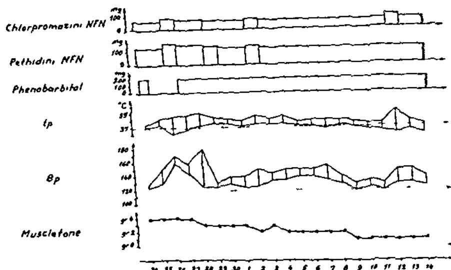


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of cerebral oedema Therefore, an attempt is made to lower the blood pressure and reduce the spontaneous, *involuntary muscle activity* by restricting afferent stimuli to the brain stem as far as is possible This is aided by restricting sound stimuli and touch to a minimum, partly by combined phenobarbitone, chlorpromazine chloride, and pethidine chloride medication

In children with the above mentioned, severe brain injuries the constant afferent impulses (sensory and proprioceptive) from the area of the fracture to the brain stem contribute highly to maintaining an increased muscle tonus and abnormal mobility patterns This again inhibits fracture stability, and a vicious circle is set up

In the present case the general de-afferentiating treatment was not sufficient to counteract the increase in tonus, presumably because immobilization of the fracture sites was insufficient It was, therefore, deemed necessary to stabilize the fractures by osteosynthesis in order to reduce the afferent impulses sufficiently and thereby improve the cerebral condition And indeed, immediately after the osteosyntheses the patient was relaxed on unchanged medication (Figure 2) In the reported case both femora were fractured, so that leg length was not likely to become unequal after the osteosyntheses In this connection it should be pointed out that the cerebral condition should always take priority to possible secondary disturbances of longitudinal growth in cases of unilateral osteosynthesis

In retrospect, another two of the patients from this hospital probably ought to have been subjected to operation Figure 3 *illustrates the* course in a 13-year-old boy with severe cerebral contusion and a low, *unstable fracture of the left lower leg For a long time there* was marked increase in tonus and an elevated blood pressure despite large *doses of sedatives Consciousness was lowered for* about 2 months, and the plaster immobilization of the lower-leg fracture proved insufficient, the fracture uniting in a poor, rotated position Furthermore, pressure wounds caused by the plaster later called for skin grafting in two sites A more stable fixation of the fracture by osteosynthesis would presumably have reduced the afferent impulses to the brain stem and thereby improved tonicity, leading to better union of the fracture The other patient was the above-mentioned 7-year-old boy with fracture of both lower legs who required 4 months treatment by intermittent ether anaesthesia and curarization Osteosynthesis of the fractures might possibly have shortened and eased this very severe course In both children *the osteosyntheses could presumably* have been performed very simply by Hoffmann's apparatus

CONCLUSION

Operative fixation of extremity fracture is usually not indicated in children. However, if severe brain injuries co-exist, the serious tonicity disturbances elicited by the brain injuries should entail contemplation of operative fixation of co-existing extremity fractures. This should be done partly to obtain optimal union of the fractures and partly to facilitate the difficult general nursing of the unconscious child.

SUMMARY

On the basis of a case of operative fixation of bilateral femoral fracture in an 8 year old boy, the treatment of fractures in children with unstable extremity fractures and co-existing severe brain injuries is discussed. It is concluded that operative fixation of extremity fractures in children may constitute an important link in their neurosurgical treatment.

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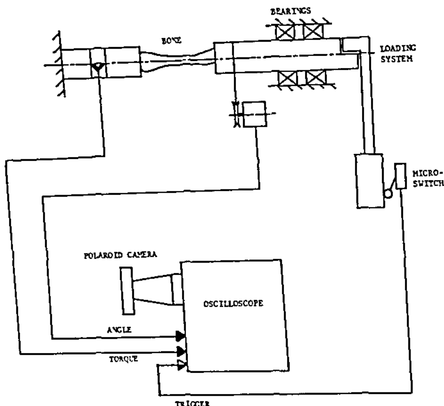


Figure 1 Block diagram of the experimental set up For description, see the text

design The answer has considerable practical importance in terms of time and money

METHOD

It was decided to employ torsional loading This was chosen because a constant load is applied to all sections of the bone irrespective of bone length or dimensions Bones are not symmetrical the left is a mirror image of the right Thus, two combinations of torsional loading are possible for a pair of bones Both bones can either be loaded in external or internal rotation, or one bone may be loaded in external and the other in internal rotation Two separate experiments were set up to test the two combinations A constant fast rate of torsional deformation was used to simulate a fracture situation

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ANALYSIS OF MECHANICAL SYMMETRY IN RABBIT LONG BONES

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It is common practice to use the unaltered member on the opposite side as a control in experimental designs using quadripeds Implicit in such an approach in biomechanical studies is the assumption that in the same animal a pair of corresponding right and left bones have similar mechanical properties There is not a good deal of experimental evidence, however, which either supports or denies this assumption Bending tests performed by Mather (1967) on twenty-eight pairs of human femurs are probably the only experiments designed for the study of symmetry with respect to the mechanical properties of bone His results support the above assumption However, a series of experiments performed on human as well as animal limbs by Singh (1971), Chhibber & Singh (1971), and Dogra & Singh (1971) show that there is statistically significant asymmetry or one-sided dominance in the bone and muscle weight of paired limbs This suggests that there may also be asymmetry of the mechanical properties of long bones To resolve the above question satisfactorily, it was decided to perform experiments to determine the relative mechanical properties of paired rabbit limb bones

This study was also conceived as a preliminary to gain some fundamental information essential for the designing of well structured, efficient biomechanical experiments In this vein, we posed the question as to whether or not the use of a paired experimental design could be expected to yield statistically significant information using less animals than would be required to get the same significance using an unpaired

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For Experiment 1, all the bones were tested in external rotation by dropping the pendulum clockwise for the left bones and counter-clockwise for the right bones. Experiment 2 required testing the right bones in internal rotation while their paired counterparts were tested in external rotation. This was accomplished by dropping the pendulum in the clockwise direction for all the bones. For both of the experiments constant rate of torsional deformation of 3.3 rad/s (190°/s) was used.

From the photographic record of each bone five quantities were calculated: maximum torque, torsional deformation, energy absorbed to fracture, torsional stiffness, and rate of torsional deformation of the bone. The traditional method of recording torque versus torsional deformation or angle gives directly the energy to fracture but gives no information regarding the rate of torsional deformation. The present method, i.e., torque and angle versus time, gives both. While the rate of torsional deformation is given by the slope of the angle time curve, the energy to fracture is obtained by

$$\text{Energy} = \int T\, d\theta = \frac{d\theta}{dt} \int T dt \qquad (1)$$

where T is the torque, θ is the torsional deformation or angle, and t is the time. Thus, energy equals the area under the torque time curve multiplied by the rate of torsional deformation. The above formula is valid under the assumption that the rate of torsional deformation $d\theta/dt$ is constant. This is true in our study as seen in *Figure 2*. Finally, torsional stiffness is measured on the major portion of the torque time curve and is given by

$$\text{Torsional Stiffness} = dT/d\theta = (dT/dt)/(d\theta/dt) \qquad (2)$$

Thus, torsional stiffness of the bone is given by the slope of the torque time curve divided by the slope of the angle time curve.

RESULTS

Experiment 1

Rabbit humeri were used for this study. Of the thirty-four pairs tested, twenty-nine pairs are reported here. The rest were discarded due to technical difficulties at some point in the testing procedure. Right and left bones were tested in external rotation. Variables studied were the same as mentioned earlier. Experimental data for all pairs of bones are given in Table 1.

Means and standard deviations of these variables for the right and left bones are shown in Table 2. Also shown are the means and standard deviation of the difference given by the formula

Limbs of thirty-four female adult New Zealand rabbits were collected within one hour of death Soft tissue was removed, and the bones were labeled, paired and deep frozen in plastic bags at −20° C It has been established that freezing has no effect on the mechanical properties of bones (Evans 1957, Sedlin & Hirsch 1966) The bone to be tested was wrapped in a paper towel which had been soaked with Ringer's-Lactate solution Its ends were molded in epoxy resin that has a curing time of ten to fifteen minutes (Plastic Padding, Göteborg, Sweden, Hirsch 1964)

The apparatus used for testing the bones consisted of a torsion testing machine and a dual beam oscilloscope The testing machine is made by A H Burstein *Shaker Heights, Ohio*, and the oscilloscope is Tektronix Type 561 B A block diagram of the set-up is shown in Figure 1 One end of the bone was held rigidly while the other end was held in a rotatable fixture The load was applied through a falling pendulum which engaged the rotatable fixture and transmitted the impact to the bone as it neared the bottom position Two transducers were provided to measure the torque and torsional deformation of the bone A micro switch, activated by the falling pendulum, triggered the oscilloscope sweep just before loading of the bone Both the torque and the angle were produced on the vertical axis of the oscilloscope screen Time was produced on the horizontal axis The recording was done with a Polaroid camera An example of the record is shown in Figure 2

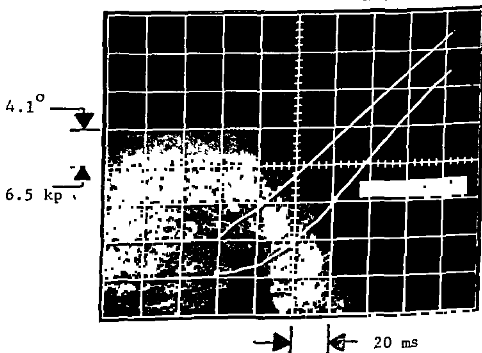


Figure 2 Oscilloscope record showing variation of torsional deformation and torque with time up to the point of fracture

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OSCILLOSCOPE RECORD

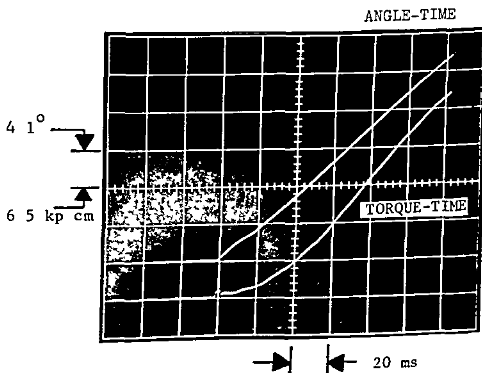


Figure 2 Oscilloscope record showing variation of torsional deformation and torque with time up to the point of fracture

Table 2 Computed results of Experiment 1

Variable	Right		Left		Difference			Relative efficiency
	Mean	SD	Mean	SD	Mean	SD	P (*t* test)	
Torque kp cm	27.5	8.75	26.6	9.87	9	9.26	0.6	0.51
Angle degrees	16.5	4.81	13.1	3.74	3.4	4.03	0.01	0.58
Energy kp cm	3.54	1.83	3.25	2.02	29	2.14	0.4	0.39
Stiffness kp cm/rad	127.6	24.9	125.7	32.7	1.9	34.6	0.7	0.30

Table 3 Data of Experiment 2 Twenty two pairs of rabbit tibiofibulae were tested Right bones were tested in internal rotation and left bones in external rotation Constant rate of torsional deformation 3.3 rad/s (190°/s) was used

Bone	Torque kp cm		Angle degrees		Stiffness kp cm/rad		Energy kp cm	
	right	left	right	left	right	left	right	left
8	30.8	23.6	13.4	9.9	3.53	2.02	68.7	65.5
10	26.4	20.5	21.8	10.7	3.70	2.00	94.9	101.5
12	12.5	23.6	7.4	14.7	0.79	2.60	49.1	52.4
13	6.5	14.4	3.3	7.8	0.26	0.99	49.1	55.6
14	31.8	33.7	21.4	17.3	6.10	5.70	81.8	108.0
16	24.2	21.0	11.9	10.3	2.60	1.94	58.9	55.6
17	15.1	11.8	7.8	7.0	1.18	0.80	52.4	58.9
22	20.6	17.2	12.0	10.0	2.18	1.40	52.4	45.8
23	18.7	14.0	7.9	6.1	1.18	0.76	72.0	58.9
24	27.8	17.1	12.8	7.4	3.36	1.18	65.5	65.5
25	19.4	25.6	7.5	9.1	1.15	2.19	68.7	78.6
26	19.7	15.1	11.9	7.8	1.98	1.06	49.1	55.6
27	23.6	24.9	9.9	11.1	2.28	2.54	65.5	65.5
29	17.1	19.7	9.5	11.6	1.60	1.79	52.4	52.4
30	17.9	22.5	10.7	12.4	1.63	2.45	88.4	94.9
33	14.0	16.0	6.4	7.1	0.83	0.99	65.5	65.5
34	16.8	14.0	8.1	6.1	1.18	0.86	62.2	58.9
35	30.0	20.2	12.4	11.1	3.80	1.60	127.7	147.3
36	22.3	13.2	11.9	5.8	2.38	0.79	85.1	58.9
37	14.0	14.8	4.9	5.4	0.73	0.76	72.0	81.8
38	17.7	24.2	14.0	19.0	2.16	3.90	72.0	78.6
39	25.6	9.2	16.2	5.8	3.78	0.42	49.1	45.8

Table 1 Data of Experiment 1 Twenty nine pairs of rabbit humeri were tested The bones were loaded in external rotation Constant rate of torsional deformation 3.3 rad/s (190°/s) was used

Bone	Torque kp cm		Angle degrees		Energy kp cm		Stiffness kp cm/rad	
	right	left	right	left	right	left	right	left
5	26 2	53 7	18 1	18 1	2 80	10 75	127 7	167 0
8	34 1	26 2	20 6	8 6	1 72	2 38	137 5	157 2
10	40 6	34 1	27 2	16 5	6 94	3 86	127 7	127 7
11	36 7	24 9	19 4	9 9	1 52	2 01	137 5	147 3
13	12 4	20 9	14 8	13 1	0 76	2 11	117 9	117 9
14	30 8	30 8	14 4	10 7	3 05	3 21	196 5	167 0
16	19 6	5 2	15 2	10 3	1 78	0 63	121 1	58 9
17	22 9	22 3	20 6	12 4	2 41	2 11	108 0	137 5
18	24 9	3 9	16 4	14 8	2 30	0 63	124 4	12 7
19	35 4	32 1	22 6	14 4	6 14	4 18	108 0	127 7
20	24 9	19 6	11 9	7 4	2 70	1 35	137 5	147 3
21	29 5	27 5	22 6	16 9	3 93	3 33	117 9	108 0
22	41 9	38 6	21 4	15 6	7 85	5 71	127 7	137 5
23	7 8	28 2	9 9	13 6	0 53	3 53	98 2	124 4
24	24 9	33 4	16 5	20 2	2 24	5 54	117 9	124 4
25	39 3	35 4	16 5	15 2	5 52	5 32	147 3	147 3
26	36 7	36 0	20 6	18 9	5 42	4 52	137 5	147 3
27	27 5	27 5	14 4	14 0	3 40	3 33	98 2	124 4
28	26 2	26 2	19 0	14 4	4 18	3 70	81 8	98 2
29	22 9	22 9	13 1	8 2	2 01	1 91	153 9	153 9
31	28 8	27 5	19 0	19 3	4 26	3 53	98 2	108 0
33	28 8	24 9	16 1	11 5	3 33	2 58	124 4	117 9
34	34 1	22 9	18 1	11 5	5 18	2 21	117 9	117 9
35	30 8	36 7	15 4	16 9	4 35	5 40	117 9	124 4
36	6 5	7 8	2 0	5 3	0 19	0 36	186 6	85 1
37	34 7	32 8	16 1	11 5	4 98	3 60	117 9	157 2
38	22 3	23 6	16 5	13 2	2 69	2 77	104 8	104 8
39	17 6	22 9	10 7	9 0	1 98	2 11	140 8	127 7
40	28 2	23 6	9 4	9 0	2 44	1 65	167 0	167 0

$$\text{Difference}(X) = \text{Right}(X) - \text{Left}(X) \tag{3}$$

where X stands for the variable under consideration The last column contains the probability as calculated by the Student's t test

Experiment 2

Rabbit tibiofibulae were used for this study Out of the thirty-four pairs tested, twenty-two were available for complete analysis because

right or left bones, as compared with a group of their fellows from the opposite side, then this difference may be considered a reliable experimental effect of the given variable

This study provides an additional important consideration from the standpoint of experimental design We have shown that the variation in the physical properties of a given long bone of different animals is a good deal greater than between paired bones of the same animal This fact has been proven statistically by the figures for relative efficiency given in Tables 2 and 4 Relative efficiency is defined as the correlation coefficient which measures the linear relationship between the right and left paired bones The value of relative efficiency varies directly with the correlation coefficient between right and left bones One can make use of this quality of symmetry in planning biomechanical experiments where the variable to be studied can be introduced on one long bone while the paired bone on the other side is used as a control Our results show that relative efficiency is greater than zero Therefore for a given statistical significance level, lesser number of animals is required if a symmetry criterium is employed Let us assume that 100 rabbits are required for an unpaired study for observing the effects of a certain fracture healing treatment Further, let the criterium for healing be the maximum energy absorbing capacity of the bone Then according to our results for a paired study, for obtaining the same level of statistical significance, we will need 100 (1–0 45) = 55 rabbits (Relative efficiency for energy for the two bones in Tables 2 and 4 is 0 39 and 0 51 respectively giving an average of 0 45) the reverse is also true i e a higher level of statistical significance can be obtained from the same group of rabbits if paired experimental design is used as compared to unpaired design

SUMMARY

Several properties of paired rabbit bones were analyzed to investigate their relative mechanical properties The following quantities were observed maximal torque, torsional deformation, energy absorbed to fracture and torsional stiffness One group of the pairs was tested by rotating each member of the pair in the same direction and another group was tested by rotating each member in the opposite direction

In both the designs for torsional loading, there was considerable variation within the pairs No pattern of right or left dominance emerged Statistical analysis showed that the observed differences were

Table 4 Computed results on Experiment 2

Variable	Right		Left		Difference			Relative efficiency
	Mean	S D	Mean	S D	Mean	S D	P (*t* test)	
Torque kp cm	20 6	6 34	18 9	5 58	1 7	6 67	0 2	0 38
Angle degrees	11 1	4 52	9 71	3 61	1 4	4 42	0 1	0 43
Energy kp cm	2 20	1 36	1 76	1 19	44	1 27	0 1	0 51
Stiffness kp cm/rad	68 3	18 5	70 6	23 7	−2 3	10 4	0 3	0 91

of the type of losses mentioned above Right bones were tested in internal rotation and left bones were tested in external rotation Experimental data for the variables are given in Table 3 The computed means, the standard deviations, and probability are given in Table 4

DISCUSSION

Results show that there is much inherent variation present in bones The variation seems to be similar in the right and left bones so that it tends to cancel out This is shown by the high values of probability noted in the calculation of the Student's *t* test applied to the 'differences' Thus, the observed average difference between right bone and left bone can be attributed to normal biological variation In other words, our hypothesis of symmetry between the paired right and left limbs of the same animal is not disproved by our data

Results of the second experiment are similar to those of Experiment 1 All the variables have high probability for the differences present in the bones to be due to normal biological variation Thus, there is no significant difference in the mechanical properties of the bones twisted internally or externally

This information is crucial to experimental designs to study the effects of a particular variable on one of a pair of long bones in rabbits Our findings have shown no evidence of a pattern of right or left dominance as regards these physical properties This suggestion, now supported with experimental evidence, provides a sound basis for a useful experimental design If a given variable can be shown to substantially alter mechanical properties of a group of randomly selected

right or left bones as compared with a group of their fellows from the opposite side then this difference may be considered a reliable experimental effect of the given variable

This study provides an additional important consideration from the standpoint of experimental design We have shown that the variation in the physical properties of a given long bone of different animals is a good deal greater than between paired bones of the same animal This fact has been proven statistically by the figures for relative efficiency given in Tables 2 and 4 Relative efficiency is defined as the correlation coefficient which measures the linear relationship between the right and left paired bones The value of relative efficiency varies directly with the correlation coefficient between right and left bones One can make use of this quality of symmetry in planning biomechanical experiments where the variable to be studied can be introduced on one long bone while the paired bone on the other side is used as a control Our results show that relative efficiency is greater than zero Therefore for a given statistical significance level lesser number of animals is required if a symmetry criterium is employed Let us assume that 100 rabbits are required for an unpaired study for observing the effects of a certain fracture healing treatment Further let the criterium for healing be the maximum energy absorbing capacity of the bone Then according to our results for a paired study, for obtaining the same level of statistical significance we will need $100\ (1 - 0.45) = 55$ rabbits (Relative efficiency for energy for the two bones in Table [illegible]

[illegible] a paired experimental design is used as compared to unpaired design

SUMMARY

Several properties of paired rabbit bones were analyzed to investigate their relative mechanical properties The following quantities were observed maximal torque torsional deformation energy absorbed to fracture and torsional stiffness One group of the pairs was tested by rotating each member of the pair in the same direction and another group was tested by rotating each member in the opposite direction

In both the designs for torsional loading there was considerable variation within the pairs No pattern of right or left dominance emerged Statistical analysis showed that the observed differences were

probably due to biologically normal variation. Thus, the assumption of mechanical symmetry in long bones was compatible with our observations in these animals. It has also been demonstrated that the use of a paired experimental design is more efficient than an unpaired design in terms of the numbers of animals required to achieve a given level of statistical significance. This information tends to confirm the validity of experimental designs which introduce a particular variable to one of a pair of long bones for the purpose of studying the effect on the mechanical properties of bone.

ACKNOWLEDGEMENTS

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NEURILEMMOMA OF PERIPHERAL NERVES

A Report of Fourteen Cases, Including Three of the Lateral Popliteal Nerve

MICHAEL LEVY, MOSHE SEELENFREUND,
PESSAH MAOR & MOSHE LOTEM

Accepted 19 ix 73

Neurilemmomas are benign tumors of the nerve sheaths They are usually painless and are often discovered accidentally (Stout 1935), very rarely causing motor disturbances (Seddon 1954, Buck-Gramcko 1958)

Neurilemmomas are most common in the upper extremities but may appear anywhere Especially rare are neurilemmomas of the lateral popliteal nerve in the region of the fibular head To the best of our knowledge only 3 such cases have previously been reported in the English literature

The following series of 14 neurilemmomas operated upon in our department included 3 cases in which there was involvement of the lateral popliteal nerve

MATERIAL

During the past 15 years in our department operations for 14 neurilemmomas found in 9 patients have been performed In 3 patients there were from 2 to 3 tumors (one patient had 3 neurilemmomas along the radial nerve) The mean age was 52 years with a range from 26 to 82 years Six patients were men and 3 women The time interval between appearance of the tumor and the operation ranged from several months to 15 years (a mean of 7 years) All of the neurilemmomas except one were tender 9 caused pain and 7 caused paresthesias Only 2 which were located near the head of the fibula caused motor disturbances Only in one case was there a post operative sensory loss All of the neurilemmomas were easily removed without any apparent damage to the nerve Complete relief was achieved in all patients except one (Case 1)

Four cases are presented in detail below In 3 there was an involvement of the lateral peroneal nerve at the head of the fibula which caused pain and paresthesias

and in 2 cases motor disturbances The fourth case presented neurilemmomas of the posterior tibial nerve at both ankle joints

CASE REPORTS

Case 1 A 48 year old clerk had intermittently complained of slight paresthesias in his left toes for several months with progressive weakness of the dorsiflexors An EMG investigation revealed that there was no voluntary action of the anterior tibialis muscle and toe extensors and no connection between the lateral popliteal nerve and these muscles There was good function of the peronei muscles It was concluded that the lateral peroneal nerve was partly damaged at the fibular head a phenomenon sometimes seen in shoemakers His past history revealed nothing that could explain the damage to the nerve On admission a soft tender tumor was palpated at the neck of the left fibula There was no sensory loss but there was dropfoot with good action of the peronei muscles There were no other findings X rays of the knee and spine were normal as were the reflexes

On operation the peroneal nerve was found to be thickened to about 1 5 cm in diameter for a length of approximately 10 cm at the neck of the fibula Opening of the sheath (Figure 1) revealed an encapsulated tumor which could be seen to be pushing some of the nerve fibers aside and entrapping others The tumor was easily removed without damage to the nerve Inside the tumor there were numerous cysts containing a gelatinous fluid Histological examination revealed an encapsulated tumor with organized elements in the form of Antony cells A in palisades and Antony cells B of myoid type It was diagnosed as a neurilemmoma

The post operative course was uneventful but the dropfoot was still present 5 years later and the patient has had to wear a special shoe The paresthesias on the other hand were relieved immediately after the operation There was no recurrence of the tumor

Case 2 A 41 year old woman with an uneventful past history was admitted because of a tender mass at the head of the left fibula which had first appeared two years previously Examination revealed no other pathological findings except for the tumor about 3×5 cm in size which was tender with radiating pain along the left leg Laboratory findings were normal Opening of the nerve sheath during operation revealed a resilient tumor (Figure 2) the size of a pigeon s egg which was easily removed without damage to the nerve Histologically this tumor also proved to be a neurilemmoma as in Case 1 The post operative course was uneventful. Eleven years later there had been no recurrence and there were no neurological disturbances

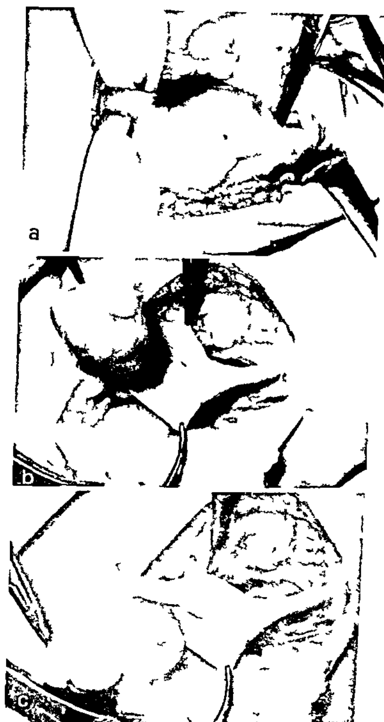
Case 3 A 41 year old man was admitted for operation because of a tumor at the head of the fibula which had appeared 4 years previously and grown slowly It was tender and there was radiated pain and paresthesias along the lateral side of the leg to the region of his fifth toe Four months before admission the pain and paresthesias had increased and paresis of the extensor of the big toe had appeared The past history was non contributory The general examination was normal except for the local finding On operation a tumor about 1 5×2 5 cm in size was found

ure 1



within the peroneal nerve (Figure 3) It was encapsulated and was easily removed without damage to the nerve fibers Histologically the findings were similar to those in Cases 1 and 2 but included cystic structures with mucoid degeneration The pathological diagnosis was neurilemmoma with degenerative intraneural cysts.

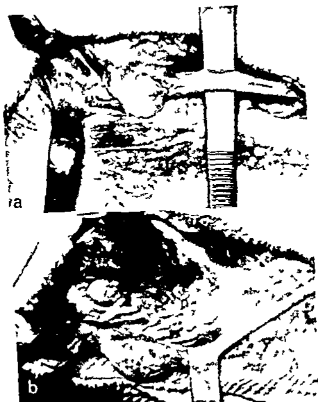
Case 4 This case is worth a brief mention because of its peculiarity. This 60 year-old man was operated upon because of a neurilemmoma of the right posterior tibial nerve which had caused him pain and paresthesias for several



F gure

years Post operatively h s symptoms disappeared b it 7 years later the same symptoms developed in the left leg and foot Three years later a neurilemmoma was removed from the ident cal s te on the left posterior t bial nerve with subsequent disappearance of the symptoms

Figure 3

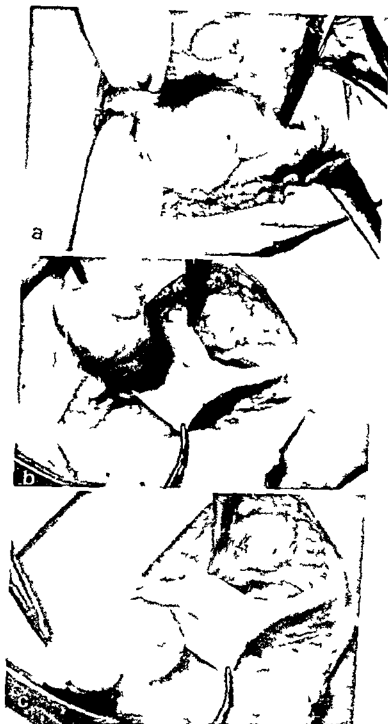


DISCUSSION

In the literature, neurilemmomas are also known by other names neurinoma and schwannoma These are benign tumors which develop from the nerve sheaths Verocay (cited by Buck Gramcko 1958) called them neurinomas in 1910, while Stout (1946) was the first to call them neurilemmoma Masson (cited by Buck-Gramcko 1958) and Buck-Gramcko (1958) use the term schwannoma

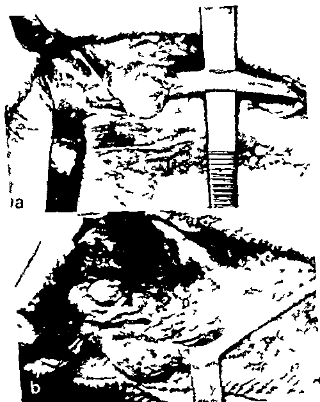
From the pathological standpoint, much has been written about neurilemmomas and neurofibromas (Stout 1935, 1946, 1949) Today, neurofibromas are differentiated from neurilemmomas, both clinically and histologically, in the latter by the use of a special staining technique According to Stout, neurofibromas are "non encapsulated and have tangled network cells showing Schwann sheath proliferation" Special staining will reveal a great number of neurites These tumors may become malignant In contrast, neurilemmomas are encapsulated

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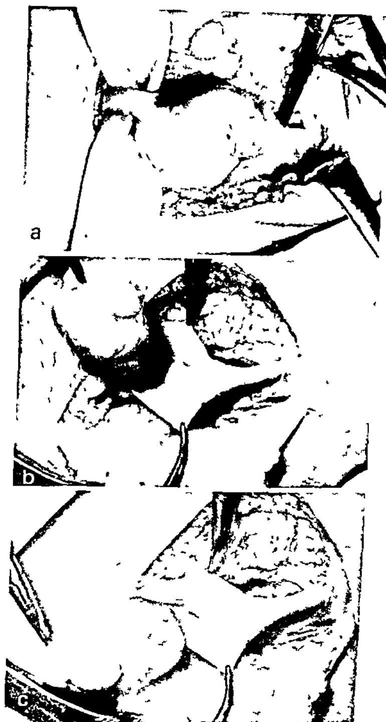


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From the pathological standpoint much has been written about neurilemmomas and neurofibromas (Stout 1935 1946 1949) Today neurofibromas are differentiated from neurilemmomas both clinically and histologically in the latter by the use of a special staining technique According to Stout neurofibromas are non encapsulated and have tangled network cells showing Schwann sheath proliferation Special staining will reveal a great number of neurites These tumors may become malignant In contrast neurilemmomas are encapsulated

Figure 2



years Post operatively his symptoms disappeared but 7 years later the same symptoms developed in the left leg and foot Three years later a neurilemmoma was removed from the identical site on the left posterior tibial nerve, with subsequent disappearance of the symptoms

larger joints, such as the elbows, hip joints and wrist joints Only rarely do neurilemmomas appear in bones (Buck Gramcko 1958, White 1967) In a few patients there seems to be a tendency for more than one tumor to develop sometimes even along a single nerve (Seddon 1954, White 1967) In our series, 3 patients had several neurilemmomas, one of them with 3 of the tumors along the radial nerve They may also occasionally appear together with neurofibromas (Stout 1946)

These tumors may appear at any age (in our series the age range was from 26 to 82 years) and men and women are equally affected (Buck Gramcko 1958, White 1967) They grow slowly and usually are accompanied by pain and paresthesia or tenderness According to Stout (1949), however, they are usually detected by accident and not because of these symptoms Seddon (1954) too states that "The neurilemmoma was infrequently diagnosed clinically because it rarely, if ever interrupted conduction"

In the series of White (1967), there was pain, local tenderness or paresthesia in 28 out of 32 patients In our series, all except one presented one or all of these symptoms White (1967) reported that the time lapse between detection of the tumor and excision was from one month up to 22 years In our series this interval ranged from a few months up to 15 years According to Buck-Gramcko (1958), there are practically no motor disturbances In our series, however, there were two cases with such disturbances, in one of which there was no postoperative improvement In one of the cases in White's series there were also motor disturbances which disappeared after the operation

Sensory disturbances are rare (Buck Gramcko 1954) Neurilemmomas are more frequently found in the upper extremities In Barrett's series (1963) 11 out of 22 were located in an upper extremity In Buck-Gramcko s series 6 patients had neurilemmomas in an upper extremity vs one patient with the tumor in a lower extremity In our series, in contrast 4 were in upper extremities and 10 in lower extremities Barret (1963) had 3 patients with neurilemmomas of the brachial plexus accompanied by motor disturbances, most of which disappeared after the operation

The reason for the dramatic course in our Case 1 is not clear It is noteworthy however, that among these 3 cases of neurilemmomas of the lateral peroneal nerve at the neck of the fibula, there was a motor deficit in two of them, in one permanent When we compare these findings with those in other series, we can see that this is unusual for neurilemmomas Comparison is not really possible, however, since neurilem-



Figure 4

and show histologically organized elements: Antoni cells A, which are typically arranged in palisades, and Antoni cells B, constituting a tissue poorer in cells, which are of a myxoid type without any special arrangement, and containing "microcysts" which sometimes fuse into larger cysts, and may occupy a large part of the tumor. These large cysts contain a gelatinous material. According to Stout neurilemmomas never become malignant. Soule (1949) states that neurilemmomas are never larger than 6 cm in length, but Seddon (1954) says that they may be from 5 to 10 cm in size In our Case 1 the length of the tumor was 10 cm, and in one neurilemmoma of the dorsal region of the foot (Figure 4) the size was even greater.

In the extremities, these tumors usually appear on the flexor aspect (Buck-Gramcko 1958, White 1967), especially the flexor aspect of the

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momas at the neck of the fibula are very rare It is possible that the location is responsible, as it is well known that the lateral peroneal nerve is very susceptible even to minor trauma or pressure (bandages P O P, etc) at this site

Barrett (1963) described in his series 4 cases of intraneural cysts (ganglia) of the external popliteal nerve, all of which presented motor disturbances and most of which recovered He does not agree with Sultan (1921) and Gurdijan et al (1965) that intraneural cysts "represent cystic degeneration in neurilemmomas"

It is possible that had our patient consulted a doctor earlier, when only paresthesias were present, the dropfoot might have been prevented Here we should like to stress the point that although neurilemmomas are rare they should be looked for in all cases of pain and paresthesias of the leg and foot

Treatment today consists of surgical excision (Seddon 1954 Buck Gramcko 1958, White 1967), i e enucleation of the tumor without damaging the nerve fibers This is easily done If any difficulty is encountered, the tumor is probably a neurofibroma and not a neurilemmoma (Buck-Gramcko 1958) There are no neurological complications after the operation and complete relief is usually attained

SUMMARY

A series of 9 patients with 14 neurilemmomas is presented Three patients with neurilemmomas of the lateral popliteal (common peroneal) nerve located near the head of the fibula are presented in detail because of the rarity of this site and one case is presented having bilateral involvement of the posterior tibial nerve The irreversible motor damage in one case which is very unusual for neurilemmomas is thought to be due to the location and the unusual susceptibility of the peroneal nerve at this site

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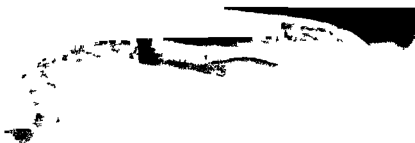
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A The joint without traction to the arms



B The joint with traction of 10 kgf to each arm in a caudal direction

Figure 2 A B The acromioclavicular joint after skin incision and traction of one kgf to the lateral end of the clavicle in a cranial direction



A Without traction to the arms



B With traction of 10 kgf to each arm

Figure 3 A B The acromioclavicular joint after division of the acromioclavicular ligament

the incision of the skin and subcutis, or, when traction was applied, following the institution of traction as mentioned, exposures being taken with and without traction of 10 kgf being applied to both arms Following the division of each new structure the procedure of repeated exposures was carried out

The dislocation gradually appearing in the joints examined was evaluated clinically by direct examination of the mobility of the clavicle and hence by the reciprocal position of the two articular surfaces, as well as by measurements obtainable from the x-ray exposures The increasing dislocation was caused partly, by a displacement in a lateral direction and a rotation of the scapula resulting in a lateral and slightly caudal displacement of the acromion, partly, by an increasing proximal displacement of the lateral part of the clavicle, the diastasis between the articular surfaces thus increasing while at the same time the angle between these surfaces changed In order to simplify the results we chose to express the extent of the dislocation by the vertical distance, in millimetres between two horizontal planes passing through the lower edges of the acromial and the clavicular articular surfaces, respectively, thus disregarding the horizontal diastasis In each case the vertical distance between the upper edge of the coracoid process and the lower clavicular surface was measured and also expressed in millimetres

RESULTS

In eight joints the division of the acromioclavicular ligament resulted in a clinically increased mobility of the joint When the joint capsule had been completely divided, the lateral part of the clavicle could be moved so far cranially as to bring the lower edge of the articular surface of the clavicle on a level with the upper edge of the acromion—the joint thus being dislocated When the muscular insertions had been cut also, the dislocation became more evident, the lower clavicular edge being displaced from 0 5–1 cm above the upper acromial edge Division of the coracoclavicular ligament increased the extent of the dislocation, the distance between the acromion and the clavicle now being from 1 5–2 5 cm

In five of the eight joints these changes could not be demonstrated radiologically, when all the muscles and ligaments, as mentioned above, around the acromioclavicular joint had been divided, x-ray exposures showed an unchanged contact between the articular surfaces of the clavicle and acromion, persisting even when traction was applied to both arms Countertraction was, therefore, as described above, applied to the clavicle in three cases, which afforded the following results, uniform for the three joints Radiological control exposures after traction had been applied showed a normal mobility of the joints (Figure 2 A, B) Division of the acromioclavicular ligament resulted in increased mobility, the x-ray exposure of the joint when no traction



A Without traction



B With traction to each arm

Figure 4 A, B The acromioclavicular joint after total division of the joint capsule

was applied showing an increased diastasis, while on application of traction the lower clavicular edge was seen to be displaced a further 2·5 mm above the lower acromial edge (Figure 3 A, B) A division of the entire joint capsule led to dislocation when traction was applied,



A. Without traction



B. With traction on each arm

Figure 5 A, B. The acromioclavicular joint after division of the joint capsule together with the muscular insertions on the lateral 2 cm of the clavicle.



A Without traction



B With traction to each arm

Figure 6 A, B The acromioclavicular joint after division of the joint capsule together with the muscular insertions and the coracoclavicular ligament



A Without traction



B With traction to each arm

Figure 5 A B The acromioclavicular joint after division of the joint capsule together with the muscular insertions on the lateral 2 cm of the clavicle



Figure 7 B Division of the joint capsule together with the coracoclavicular ligament —with muscular insertions left intact



Figure 7 C Division of the joint capsule together with the coracoclavicular ligament and the muscular insertions

All pictures are with traction of 10 kgf to each arm

the lower clavicular edge being on a level with the upper acromial edge (Figure 4 A, B) When no traction was applied, the cutting of the insertions of the muscles from the clavicle resulted in subluxation in one case, and in dislocation in two cases while, when traction was applied, dislocation occurred in all cases, the distance between the lower edges of the acromion and the clavicle being at least 12 mm (Figure 5 A, B) When the coracoclavicular ligament was divided, dislocation was registered radiologically whether or not traction was applied (Figure 6 A, B)

In one case counter-traction was also applied, but the order in which the different divisions were made was altered Following division of the joint capsule application of traction to the joint showed a clinical as well as radiological dislocation, similar to that found in the previously examined cases Division of the coracoclavicular ligament without any lesion of the muscles left the clinical mobility and the radiological picture of the joint practically unchanged (Figure 7 A, B) Only after division of the muscular insertions, as mentioned above, did the more distinct dislocation become apparent, whether or not traction was applied (Figure 7 C)

In the four cases in which counter-traction was applied to the joint radiological measurements revealed a primary distance of 6–11 mm between the coracoid process and the clavicle In all cases of dislocation



Figure 7 A The acromioclavicular joint after total division of the joint capsule and the acromioclavicular ligament

between the coracoid process and the clavicle of at least 13 mm, and the distance between the lower edges of the clavicle and the acromion exceeds 20 mm Complete instability of the joint may be found without any rupture of this ligament, and reconstructive procedures involving the ligament only thus appear irrelevant and rather unsuccessful in the treatment of acromioclavicular dislocations

The results of post mortem experiments can hardly be applied directly to the conditions of the living organism, the muscles surrounding the joint apparently having special significance for the stability of the joint even so, we consider our experimental procedure a realistic imitation of the forces influencing the acromioclavicular joint

SUMMARY

The results of post mortem investigations of the acromioclavicular joint are presented They concern experiments involving division of the structures around nine joints, the mobility of which has been examined clinically and radiologically It is demonstrated, clinically as well as radiologically, that acromioclavicular dislocation may occur without injury of the coracoclavicular ligament

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with an intact coracoclavicular ligament, this distance increased, the maximum increase being 7 mm Division of the coracoclavicular ligament led to an increase of a further 6 to 20 mm, except in the case in which the muscles remained intact—the increase amounting to only one mm Only on division of the muscles did this distance increase by a further 6 mm

DISCUSSION AND CONCLUSION

Ever since the first experimental investigations of the pathological anatomy of the acromioclavicular joint (Cadenat 1917) the significance of the coracoclavicular ligament for the stability of the joint has been a subject of discussion On the basis of post-mortem experiments in five joints not controlled radiologically Urist (1946) concluded that dislocation could take place without the presence of injury to this ligament, and operative investigations in patients with dislocation have corroborated this (Horn 1954) Even so, other authors (Watson-Jones 1956, Brosgol 1961, Stewart 1963 and Biedeberger et al 1970) have later maintained that rupture of the ligament is a prerequisite for dislocation, as a radiological demonstration of an increase in the distance between the clavicle and the coracoid process has been made in all cases with dislocation

In our opinion our clinical investigations corroborate Urist's findings and our radiological results are in complete accordance with the same A dislocation of the acromioclavicular joint may be present, clinically as well as radiologically, without any injury of the coracoclavicular ligament being present The length of this ligament allows for a displacement of the lateral end of the clavicle in a proximal direction resulting in a radiological increase in the distance between the clavicle and the coracoid process An increase in this distance up to 7 mm is thus a useless indication, seen from a diagnostic point of view, as far as the question of a rupture of the ligament is concerned

In our experience the diagnosis, dislocation of the acromioclavicular joint, should be established by x ray exposures of the joint in question and with traction of 10 kgf applied to both arms, and a comparison with the opposite, uninjured joint should be made the reciprocal position of the articular surfaces being the determining factor Any possible injury of the coracoclavicular ligament can only be definitely demonstrated by surgical intervention, but its presence is considered probable, when the dislocation results in an increase in the distance

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DISPLACED PROXIMAL HUMERAL FRACTURES

A Review of 49 Patients

HENRIK SVEND-HANSEN

Accepted 27 viii 73

It has often been stated that fractures of the neck of the humerus are best treated by simple measures such as a sling or hanging cast, and that early mobilization is essential (Moriber & Patterson 1967, Einarsson 1958)

It is the aim of this paper to demonstrate whether this is true or not where displaced proximal humeral fractures are concerned

MATERIAL AND METHOD

The journals of patients with fracture of the neck of the humerus admitted to the Surgical Departments D H, R S and T, Copenhagen County Hospital Gentofte, over a five year period from 1966 to 1971 were studied and the patients divided into two groups

1 84 patients with slight displacement of the fragments admitted for other reasons (age other lesions)
2 63 patients with considerable displacement of the fragments, but without dislocation of the head fragment

Only group no 2 was reviewed Eight patients were dead at the time of examination which left 55 patients Of the remaining 55 patients 49 were examined. One patient had disappeared and five patients would not appear The percent reviewed was thus 89 per cent

All the patients had previously answered a questionnaire regarding their complaints and this was completed by re-examination including a clinical and radiological examination

The journals and X rays were studied and compared with the findings at the re examination The minimum follow up time was 1½ years, maximum 7 years Only patients above 20 years were included in the material.

RESULTS

The age and sex distribution of the patients are shown in Table 1.

The anatomical classification was made in accordance with the Neer classification (Neer 1970)

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Table 3 Overall results

Neer classification	No of patients	Per cent	Per cent
Excellent	12	25	
Satisfactory	7	14	39
Unsatisfactory	7	14	
Failure	23	47	61

Excellent > 89 units
Satisfactory 80–89 units
Unsatisfactory 70–79 units
Failure < 70 units
Maximum score 100 units

Table 4 Average score according to fragmentation

Fragmentation	Average score	Lowest score	Highest score
2 fragments	75 5	43	94
3 fragments	73 1	36	97
4 fragments	63 6	30	98

Overall average score 71

Table 5 Treatment and results of treatment

Treatment	No of patients	Average score	Lowest score	Highest score
Sling	12	72	39	95
Hanging cast	21	68	41	92
Reduction	6	89	66	97
Osteosynthesis (rush)	3	71	50	98
Extirpation of the head	5	47	30	61
Plaster cast (thoraco brachial)	2	75	74	76

The overall results are shown in Table 3

It is worth noting that in 61 per cent of the patients the result was classified as unsatisfactory or a failure, and that nearly half the results were failures

The average score in relation to fragmentation is shown in Table 4 As expected the score is lower in the more comminuted fractures, but

Table 1 Age and sex distribution

Sex	No of patients	Per cent	Average age
Male	14	29	64
Female	35	71	69

Youngest patient 29 years
Oldest patient 94 years

2 fragments Fracture of the neck of the humerus

3 fragments Fracture of the neck of the humerus and avulsion of the greater tubercle

4 fragments Fracture of the neck, the greater tubercle, and the lesser tubercle

No attempt was made to classify the fractures as abduction or adduction types, as this and other classifications are worthless (Neer *1970*)

Table 2 Anatomical classification

Fragmentation	No of patients	Severity of displacement	
2 fragments	12	Slight	3
		Moderate	8
		Severe	1
3 fragments	22	Slight	1
		Moderate	13
		Severe	8
4 fragments	15	Slight	0
		Moderate	4
		Severe	11

Table 2 shows the *anatomical appearance*

The results were evaluated according to the Neer criteria (Neer 1970) The maximum score is 100 units divided on the following points

Pain	35 units
Function	30 units
Range in motion	25 units
Anatomy	10 units

into the failure group Four patients are fully satisfied in spite of being classified as failures

Four patients had to give up their work because of the fracture, and 26 of the 49 patients examined were pensioners and many stated that they were disabled in their daily work

DISCUSSION

The investigation showed that, contrary to the findings of other authors (Morber & Patterson 1967), the results were not encouraging The average score was 71, a very low figure, and almost half the results were failures Only 25 per cent were excellent Two and three fragment fractures were generally better than four fragment fractures Removal of the head of the humerus was disastrous All five patients were classified as failures

Apart from the five patients who had the head fragment removed, only three patients underwent surgery, in all cases Rush osteosynthesis Only one had an excellent result

The remaining 41 patients were treated by closed methods

Einarsson (1958) states that 80 per cent of three and four fragment fractures treated conservatively have a good result This is in rather sharp contrast to my findings Neer (1970) has treated a consecutive series of 117 patients with three and four fragment fractures and analyzed the result of closed reduction open reduction and fixation, and prosthetic reconstruction Closed reduction was found inadequate in both categories whereas the preferred method for three fragment fractures was open reduction and that for four fragment fractures was prosthetic replacement In 1957 Knight & Mayne suggested prosthesis in patients with fracture dislocations and comminuted fractures No patients in the present series had prosthetic reconstruction, and this method is not widely accepted in this country

The question is now whether at least 60 per cent of the patients would not have been better off with another form of treatment Neer's (1970) results are a lot better for three and four fragment fractures treated operatively

This paper shows that the conservative treatment and the extirpation of the humeral head do not give satisfactory results, and a more active treatment including open reduction and fixation and prosthetic replacement (assuming a correct selection of the patients) should be the future treatment of choice

both good and bad results are obtained in the three groups as shown in the two columns to the right

Six different methods of treatment were employed, and the results are shown in Table 5

Table 6 Results of the five patients treated by extirpation of the head of the humerus

Age	Sex	Fragmentation	Displacement	Score
66	female	3 fragments	moderate	36
74	female	3 fragments	severe	61
71	female	3 fragments	severe	50
50	female	4 fragments	severe	30
67	female	4 fragments	severe	60

Table 7 The patient's own opinion related to that of the surgeon

Patient's opinion	No of patients	Group classification				Average score
		Excellent	Satisfac	Unsatisf	Failure	
Fully satisfied	19	9	5	1	4	82
Partly satisfied	22	3	2	6	11	70
Not satisfied	8	0	0	0	8	46

As we are dealing with different types of fractures with a varying degree of displacement, the figures are too small to allow a definite conclusion Reduction under general anaesthesia, however, seems to give a good result, but the removal of the humeral head resulted in failure This was done in five cases and the result is demonstrated in Table 6 All the results were failures with very low scores, the patients complaining of pain, loss of range of motion, and loss of stability The fractures treated in this way differed in no way from the rest

Necrosis of the head fragment was seen in four patients with the scores 42, 47, 50 and 62 i e all failures There were no cases of pseud arthrosis

All the patients were asked about their opinion of the result and this is shown in Table 7 Generally there is a good correlation between the patient's and the surgeon's opinion All the dissatisfied patients fall

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COMPLETE LESION OF THE MEDIAN NERVE ASSOCIATED WITH DISLOCATION OF THE ELBOW JOINT

N A Rana, J Kenwright, R G Taylor & G Rushworth

Accepted 22 x 73

Complete lesions of the median nerve after dislocations of the elbow joint are uncommon injuries usually associated with severe compound fracture dislocations (Linscheid & Wheeler 1965, Roberts 1969, Watson Jones 1930, Wilson 1938) There is only one case previously recorded in which there was a complete median nerve lesion associated with a closed dislocation of the elbow without fracture (Gurdjian & Smathers 1945) In this instance and in one other report of a partial median nerve lesion (Mannerfelt 1968), the nerve was found at operation to be entrapped within the elbow joint

The purpose of this paper is to describe the case of a child who developed a complete median nerve lesion after closed postero-lateral dislocation of the elbow joint and to discuss some of the difficulties of diagnosis and treatment

CASE REPORT

On 18 1 1968 an 8 year old boy fell from a tree and sustained an apparently uncomplicated postero lateral dislocation of the left elbow joint without fracture Pre-reduction neurological examination was recorded as normal Reduction was performed under general anaesthetic without any undue use of force Neurological examination made 12 hours after reduction was also recorded as normal The patient was discharged from hospital in a plaster of Paris posterior splint after 24 hours Hospital follow up appointments were poorly attended and the patient presented again 8 weeks after injury the mother complaining that the boy had not been using his thumb or index finger for 3 weeks Examination demonstrated loss of sensation in the median nerve distribution and loss of the power of flexor pollicis longus flexor digitorum profundus of the index finger, flexor digitorum sublimis and abductor pollicis brevis Needle electrode electromyograms from the abductor pollicis brevis showed profuse fibrillation and no response of motor units on voluntary effort Electrical stimulation of the digital nerves in the median nerve distribution failed to evoke any sensory potential and there was no motor

SUMMARY

A review of 49 patients with displaced proximal humeral fractures was carried out The aim was to establish whether the old assertion was true that these fractures were best treated by conservative methods and that the results were good It was found that 47 per cent were failures and 14 per cent unsatisfactory Extirpation of the humeral head always resulted in failure A more active treatment including open reduction or prosthetic reconstruction in severe fractures is re commended

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Accepted 22.x.73

Complete lesions of the median nerve after dislocations of the elbow joint are uncommon injuries usually associated with severe compound fracture dislocations (Linscheid & Wheeler 1965, Roberts 1969, Watson Jones 1930, Wilson 1938). There is only one case previously recorded in which there was a complete median nerve lesion associated with a closed dislocation of the elbow without fracture (Gurdjian & Smathers 1945). In this instance and in one other report of a partial median nerve lesion (Mannerfelt 1968), the nerve was found at operation to be entrapped within the elbow joint.

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CASE REPORT

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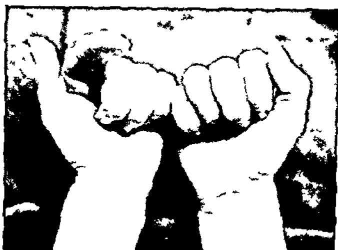


Figure 1 The median nerve lesion in the left hand just before exploratory operation, patient attempting active flexion of digits of both hands

response to high intensity stimulation of the median nerve at the wrist, in the cubital fossa and in the axilla A diagnosis of complete median nerve lesion was made but due to failed attendances the next examination was one year after injury At this time the boy claimed he had sensation in the median nerve distribution, but there were trophic changes and motor loss as at the previous examination (Figure 1) A repetition of the electro physiological examination again produced evidence of a complete median nerve lesion at the level of the elbow Surgical exploration was therefore performed

Operative Findings

The bicipital aponeurosis was divided but the median nerve could not be seen anterior to the elbow joint The nerve was exposed and traced from more proxim

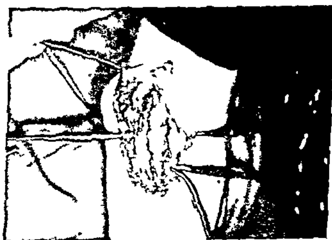


Figure 2 Median nerve dipping into the elbow joint at operation, and the disparity between the size of two ends of the median nerve



Figure 3 End to end repair of median nerve with the elbow flexed

ally and more distally towards the elbow where it was found to be dipping into the region of the elbow joint (Figure 2) Further dissection through dense fibrous tissue anterior to the joint showed that a complete division of the median nerve had occurred within this region leaving a gap of two centimetres between the proximal and distal ends The diameter of the proximal end was markedly broader than the distal end End to end repair was performed and the elbow immobilised in flexion (Figure 3)

Progress

Recovery of median nerve function was progressive Follow up examination performed 20 months after nerve repair showed good clinical function (Figure 4) *Motor power was then as shown in Table 1* The patient could feel a von Frey hair of 4 08 g on the tip of the thumb and 4 17 g on the tips of the other fingers supplied



Figure 4 Active flexion of thumb and index finger of left hand 20 months after the operation

Table 1 Post-operative muscle function

	Power (Medical Research Council Scale)				
	Thumb	Index	Middle	Ring	Little
Flexor digitorum profundus		4–5	4–5	5	5
Flexor digitorum sublimis		4	4	4	4
Flexor pollicis longus	5				
Opponens pollicis	5				
Abductor pollicis brevis	5				

by the median nerve (A normal control perceived hairs of 2·36–2·44 g) There was a full range of motion in the left elbow joint An electrophysiological examination confirmed that reinnervation was progressing Recordings from the left abductor pollicis brevis showed no spontaneous activity at rest Maximum voluntary effort evoked five to six single motor units reaching 500 microvolts in amplitude, of long duration and polyphasic The maximum conduction velocity of the motor nerve fibres innervating these units was 60 meters per second proximal to the elbow 34 meters per second distal to the elbow, and the peripheral delay was 5 milliseconds which was a little prolonged Electrical stimulation of the digital nerves of the left *thumb evoked a small sensory potential* (one microvolt) in the median nerve proximal to the left wrist, and the velocity of the propagation through the hand to the wrist was only 16 meters per second No potential could be evoked from the index finger

DISCUSSION

The case of a child who developed a complete median nerve lesion after postero lateral dislocation of the elbow joint has been described Clinical examination did not reveal the median nerve lesion until 8 weeks after injury Surgical exploration demonstrated the nerve to have been completely divided This damage could have occurred at the time of the initial trauma or by entrapment of the nerve within the elbow joint during reduction as has been described previously (Gurdjian & Smathers 1945, Mannerfelt 1968)

Diagnosis may be difficult in children In adults sensory findings are more reliable than motor signs as indicators of median nerve function (Boswick & Stromberg 1967), but in a child the assessment of sensation may be difficult Electrophysiological examination may be a useful diagnostic procedure to assess the severity of the lesion in such cases Seddon (1947) described neurotmesis and axonotmesis as being indistinguishable at initial clinical examination and one of the problems in diagnosis is the assessment of which type of nerve lesion is particu-

larly associated with a particular skeletal injury Closed injuries around the elbow joint are almost always associated with a neuropraxia or very rarely an axonotmesis and usually recover without operation The case described here demonstrates that this may not always be so even after an apparently simple posterior dislocation of the elbow joint in a child If a lesion is diagnosed, careful follow up is required as it cannot be assumed that spontaneous recovery will follow

SUMMARY

A complete lesion of the median nerve associated with a closed dislocation of the elbow joint in a child is described and some of the diagnostic difficulties which were encountered are discussed

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ENTRAPMENT OF THE POSTERIOR INTEROSSEOUS BRANCH OF THE RADIAL NERVE IN RHEUMATOID ARTHRITIS

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One of the branches of the radial nerve, the posterior interosseous nerve, is subject to entrapment neuropathy in rheumatoid arthritis (rh a)

Compression of the posterior interosseous nerve is followed by weakness of the following muscles extensores digitorum communis, digiti V proprius and carpi ulnaris, abductor pollicis longus, extensores pollicis and extensor indicis proprius

The dorsiflexion of the wrist is not considerably impaired because the *power of extensores carpi radiales remains unchanged* However, ulnar abduction of the wrist becomes heavily outweighed by the strength of the radial abduction

The distal part of the nerve gives off branches to the carpal joints However, sensory disturbances are rare

Spinner (1972) considers entrapment neuropathy of the posterior interosseous nerve to be a rare complication in rh a Marmor et al have published one case (1967) and Chang et al another (1972)

Popelka et al (1969) studied 123 rh a patients with involvement of the elbows In 30 hands (12 per cent) marked weakness of finger extension was found which could not be explained by distal changes *A synovectomy of the elbow with removal of the* radial head was performed in all of these cases The improvement of the power of the finger extensors *was measured with Mannerfelt's abductometer* One typical case is illustrated in Figure 2

Figure I clearly shows *the vicinity of the posterior interosseous* nerve and the radial head It also demonstrates the fact that the nerve can be easily damaged when the radial head is removed (*Strachan & Ellis* 1971) Resection of the radial head is a common operation in rh a It has been performed about 900 times at our hospital In one case it

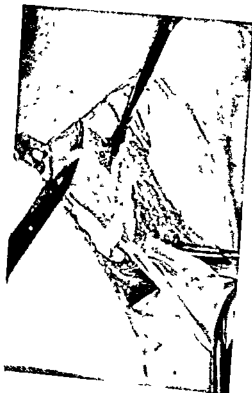


Figure 1 The posterior interosseous nerve, entering under the arcade of Frohse, is isolated by the rubber band The tip of the probe indicates the place of the removed radial head.

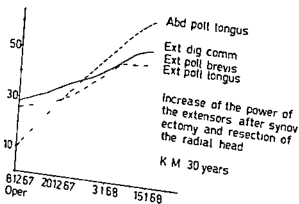


Figure 2 Diagram showing the increase in the power of some extensor muscles after resection of the radial head and synovectomy of the elbow Numbers on the ordinate indicate the degrees on the dial of the dynamometer.

was followed by permanent weakness of the finger extensors Otherwise in rh a a carefully performed synovectomy of the elbow combined with resection of the dislocated or deformed radial head is sufficient to decompress the posterior interosseous nerve

CONCLUSIONS

Entrapment syndrome of the posterior interosseous nerve is a fairly frequent complication in rh a It has to be considered on every occasion when the elbow is involved and the weakness of the finger extensors cannot be explained by distal changes Entrapment of the *posterior interosseous nerve may also contribute to the development* of the common radial deviation of the carpus in rh a

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MANUAL SENSING OF FRACTURE STABILITY: A BIOMECHANICAL STUDY

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In the closed management of fractures of long bones the physician must decide when the injured limb may assume normal function unsupported by external stabilization This decision to remove the final cast is based on several criteria of healing such as adequate elapsed time a pain free limb, a non tender fracture site, firm localized callus, painless active function of local musculature, roentgenographic criteria of healing and finally in appropriate cases, a test of fracture stability applied by the physician in the form of an attempt to evaluate bending of the fracture site under a manually applied bending moment (Figure 1)

While applying the moment, the physician judges patient discomfort and fracture segment stability both by "feel" and visual determination of angular deformation

Frequently patients may feel pain during such a test while the physician reports that the fracture feels "springy" He may judge that there is insufficient stability, the patient must continue to wear a cast or be otherwise supported A continuing feeling of instability even in the face of roentgenograms which show apparent solid union (Figure 2) may lead to a decision that the fracture is failing to unite solidly

The judgement of relative stability is based on two variable factors, the applied moment force and the visual and manual sensitivity of the physician in detecting motion and angular deformation Excessive bending force may cause a refracture while an inadequate test may lead to a premature decision to abandon the cast

This study was designed to determine the magnitude of the moment force applied by a group of orthopaedic surgeons when testing fractures for stability and to evaluate the variability within the group In addi-



Figure 1 A typical manual test for forearm fracture stability

tion, an effort was made to analyze the visual and manual sensitivity of the physician groups in detecting angular deformation, and to determine the relative stability present when the surgeon makes the decision that the fracture is healed These results were sought in view of the difficulty in teaching residents what an appropriate moment force is when one surgeon knows precisely what testing force he usually applies or what level of stability is satisfactory for unsupported function

METHODS

Design and Calibration

An instrument (Figure 3) has been designed to simulate a midshaft fracture of a long bone The design includes two 28 centimeter lengths of 1 6 centimeter diameter steel pipe with a 3 millimeter wall thickness A stranded steel cable 3 millimeters in diameter is positioned through the longitudinal axis of the aligned pipe segments One cable end is attached to a sliding screw pretensioning device The opposite end is affixed to a strain gauge instrumented beam which provides continuous measurement of cable tension Flanges at the interfacing pipe ends form the simulated fracture site The flanges provide a fulcrum effect whereby bending moments and corresponding angulations applied across the site yield appropriately measurable cable tension changes A thin rubber sheet is interposed between the flanges to decrease a mechanical feeling and to eliminate noise when the device is employed The length of the apparatus is covered with two layers of sponge rubber to duplicate the feeling of soft tissue over bone

Cable pretension as controlled by the sliding screw attachment enables experimental variation of fracture site bending stiffness defined to be the applied moment versus angulation relationship Stiffnesses were determined for an appropriate range of cable pretensions by calibration in an Instron floor model testing machine

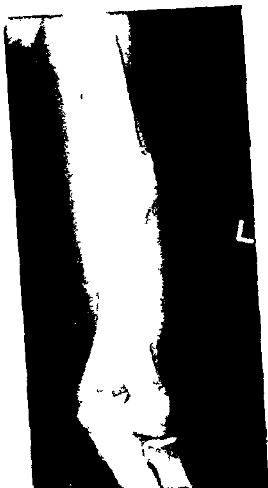


Figure 2 A clinically unstable humeral shaft fracture despite good roentgenographic evidence of healing

Strain gauge instrumentation recordings made during calibration serve a two fold function The first is determination of cable tension settings prior to the application of fracture site bending moments second calibration of subsequent applied moment angulation conditions as measured by cable tension increases These combined results are shown in Figure 4 to be interpreted as follows The values 150 275 and 300 are strain gauge measures of three cable pretension settings The three settings yield increasing fracture site stiffnesses as plotted to the left in the figure For example the 150 275 and 300 settings subsequently require 80 kgf cm 100 kgf cm and 125 kgf cm moment magnitudes respectively to produce a 3 degree angulation at the fracture site Note that the pretension settings serve only to identify calibrated stiffness curves and do not imply further signifi

FRACTURE SIMULATOR

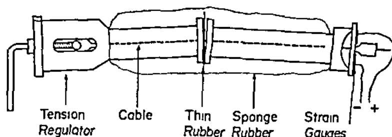


Figure 3 The fracture simulator

cance Figure 4 on the right shows calibrated strain gauge output readings which correspond to increased cable tensions caused by the application of fracture site bending moments Thus an output reading of 78 denotes for a 150 setting the application of a 76 kgf cm moment and a resulting 2 5 degree angulation at the fracture site The above outlined calibration procedure was conducted over a stiffness range from the simulation of a rubbery or springy fracture to progressively pretensed cable settings at which the stimulated fracture seemed to be solidly united

Test Protocol

Ninety orthopaedic surgeons were tested They were divided into three groups residents (39) orthopaedic surgeons with 0–10 years experience after residency (26) and those with greater than ten years experience (25)

First the subject physician was told to consider the instrument a nearly healed undisplaced midshaft fracture of both bones of the forearm which had been treated closed by long arm casts The limb was to be considered pain free and the roentgenograms had demonstrated satisfactory progression toward healing The subject surgeons were asked to apply to the simulated fracture that moment force they would normally use for a test of the healing fracture at the time a decision to continue or discontinue cast treatment must be made The instrument was pretensioned at the 150 stiffness setting for all subjects The test was repeated approximately six times to insure device familiarity and to determine consistency Characteristic test one recorded results are shown in Figure 5 The bending moment values to be reported are the averages of the three most similar individual test results

To validate the chosen degree of controlled stability subjects were asked in this test whether they felt that the fracture was sufficiently stable to discontinue cast treatment Their responses were recorded 25 per cent positive and 75 per cent negative indicating that the pretension stiffness level indeed simulated that representative of a nearly or just healed fracture

In the second test the instrument was adjusted to provide gross angulation with a minimal bending moment simulating a very unstable fracture While the subject was asked to repeatedly test the simulated fracture for stability the apparent fracture stiffness was progressively increased until the surgeon reported that the

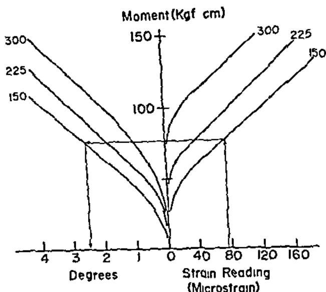


Figure 4 Nomogram used to determine test moment and angular deformation values at the three pretension levels

fracture was sufficiently stable for unsupported function The recorded cable pretension at the time of this decision measures the *fracture stiffness* required for a "healed" decision (Figure 5) Force and angulation at the "healed" decision were recorded This bending moment force allows a comparison between the first test force magnitude and that actually used at the time of the simulated decision Relative consistency was again evaluated Lastly, the bending moment used by the subjects at the first test stiffness level was compared when applicable, to that recorded when the simulated fracture stiffness passed the same level in the second test

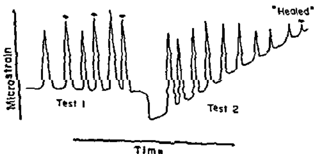


Figure 5 A sample test record Arrows in Test 1 indicate the three test results chosen for further evaluation The arrow in Test 2 is the recorded value when the surgeon declared the simulated fracture "healed

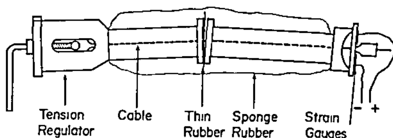


Figure 3 The fracture simulator

cance Figure 4 on the right shows calibrated strain gauge output readings which correspond to increased cable tensions caused by the application of fracture site bending moments Thus an output reading of 78 denotes, for a 150 setting the application of a 76 kgf cm moment, and a resulting 2 5 degree angulation at the fracture site The above outlined calibration procedure was conducted over a stiffness range from the simulation of a rubbery or springy fracture to progressively pretensed cable settings at which the stimulated fracture seemed to be solidly united

Test Protocol

Ninety orthopaedic surgeons were tested They were divided into three groups, residents (39), orthopaedic surgeons with 0–10 years experience after residency (26), and those with greater than ten years experience (25)

First, the subject physician was told to consider the instrument a nearly healed undisplaced midshaft fracture of both bones of the forearm which had been treated closed by long arm casts The limb was to be considered pain free, and the roentgenograms had demonstrated satisfactory progression toward healing The subject surgeons were asked to apply to the simulated fracture that moment force they would normally use for a test of the healing fracture at the time a decision to continue or discontinue cast treatment must be made The instrument was pretensioned at the 150 stiffness setting for all subjects The test was repeated approximately six times to insure device familiarity and to determine consistency Characteristic test one recorded results are shown in Figure 5 The bending moment values to be reported are the averages of the three most similar individual test results

To validate the chosen degree of controlled stability subjects were asked in this test whether they felt that the fracture was sufficiently stable to discontinue cast treatment Their responses were recorded 25 per cent positive and 75 per cent negative, indicating that the pretension stiffness level indeed simulated that representative of a nearly or just healed fracture

In the second test the instrument was adjusted to provide gross angulation with a minimal bending moment, simulating a very unstable fracture While the subject was asked to repeatedly test the simulated fracture for stability the apparent fracture stiffness was progressively increased until the surgeon reported that the

ble 2 *Stimulatel fracture initial stiffness anl test moment with the associated angular deformation at the time of the surgeons' decision healed fracture*

	Number	Relative simulated fracture stiffness (Micro strain)	Range	Bending moment (kgf cm) ± 1 S D	Range	Angular deformation (degrees)	Range
iedic ts	39	231±74	375–100	97 6±30 9	49 2 156 0	2 6±1 1	1 0–5 0
aedic ns with ars ence	26	254±85	450–100	98 4±29 2	44 2 138 4	2.3±0 7	1 0–4 0
paedic ons with r than ars ience	25	274±70	350–90	87 6±24 2	45 9 138 4	2 1±0 5	1 0–3 5
oups	90	239±75	375–90	95 0±29 2	44 2 156 0	2.3±0 8	1 0–5 0

Figure 4 calibration curves There are no significant differences in means or variances for this stiffness measure as related to experience The relatively small standard deviation indicates most physicians made the simulated decision to discontinue immobilization at approximately the same stage of healing The limits of this range (90–375) do indicate, however that a few physicians deviate considerably from the average

At the decision "healed the bending moment and angulation values were 95 0±29 2 kgf cm and 2 3±0 8 degrees respectively Averages of both are not significantly different for the group comparisons As in test one however the variance ratio test again shows a trend toward uniformity with experience Bending moment variances for residents compared to orthopaedic surgeons with more than 10 years experience are significantly different at $P < 0\ 1$ Angulation variances, residents compared to the less than 10 years experience and the less than 10 years experience group compared to the more than 10 years experience group are significantly different at $P < 0\ 05$

The test two moment applied at the "healed' decision is not significantly different from the results of test one, demonstrating that the tested physicians do indeed apply a controlled standard bending

Table 1 Bending moment and associated angular deformation for a simulated both bones of the forearm fracture tested for stability by orthopaedic surgeons

Group	Number	Bending Moment (kgf cm±1 S D)	Range	Angular deformation (degrees, ±1 S D)	Range
Orthopaedic residents	39	104 3±25 9	55 0–155 9	3 3±0 3	1 8–4 0
Orthopaedic surgeons with 0–10 years experience	26	100 1±23 4	64 2–138 4	3 2±0 3	2 2–3 8
Orthopaedic surgeons with greater than 10 years experience	25	81 7±20 0	48 4–126 8	2 7±0 3	1 6–3 5
All groups	90	96 7±25 0	48 4–155 9	3 2±0 3	1 6–4 0

RESULTS

The average bending moment used by the physicians when testing a stimulated forearm fracture was 96 7 ± 25 0 kgf cm (Mean ± 1 Standard Deviation) The associated angular deformation was 3 2±0 3 degrees (Mean ±1 Standard Deviation) Table 1 presents the average bending moments and associated angular deformations

The first test as presented above investigates the bending moment applied by our 90-surgeon sample when testing a simulated, both bones of the forearm fracture for healing Overall and experience grouping results are presented in Table 1 Although experienced physicians appear to use less bending force (81 7±20 0 kgf cm) than the other two groups, this impression is not substantiated by student t-tests at a $P = 0\ 1$ level of significance Decreasing magnitudes of standard deviation values do demonstrate a trend toward uniformity with experience A variance ratio test, using the F distribution, for residents compared to surgeons with greater than 10 years experience, shows a population variance difference exists at $P < 0\ 1$

In test two (Table 2) the physicians declared the fracture stabilized at a 239±75 cable pretension setting Recall that this value is a measure of fracture site stiffness, and must be interpreted in the context of

Table 2 Stimulated fracture initial stiffness and test moment with the associated angular deformation at the time of the surgeons decision healed fracture

ıp	Number	Relative simulated fracture stiffness (Micro strain)	Range	Bending moment (kgf cm) ± 1 S D	Range	Angular deformation (degrees)	Ran
ıopaedic dents	39	231±74	375–100	97 6±30 9	49 2–156 0	2 6±1 1	1 0–5
ıopaedic geons with) years erience	26	254±85	450–100	98 4±29 2	44 2 138 4	2 3±0 7	1 0–4
hopaedic geons with ater than years erience	25	224±70	350–90	87 6±24 2	45 9–138 4	2 1±0 5	1 0–3
groups	90	239±75	375–90	95 0±29 2	44 2–156 0	2 3±0 8	1 0–5

Figure 4 calibration curves There are no significant differences in means or variances for this stiffness measure as related to experience The relatively small standard deviation indicates most physicians made the simulated decision to discontinue immobilization at approximately the same stage of healing The limits of this range (90–375) do indicate, however, that a few physicians deviate considerably from the average

At the decision 'healed' the bending moment and angulation values were 95 0±29 2 kgf cm and 2 3±0 8 degrees respectively Averages of both are not significantly different for the group comparisons As in test one, however, the variance ratio test again shows a trend toward uniformity with experience Bending moment variances for residents compared to orthopaedic surgeons with more than 10 years experience, are significantly different at $P < 0\ 1$ Angulation variances, residents compared to the less than 10 years experience and the less than 10 years experience group compared to the more than 10 years experience group, are significantly different at $P < 0\ 05$

The test two moment applied at the "healed" decision is not significantly different from the results of test one, demonstrating that the tested physicians do indeed apply a controlled standard bending

moment as fractures become more stable In addition, the test one bending moment at the 150 pretension setting is not significantly different than that applied in test two as the stiffness setting was increased through the same value There is thus a remarkable consistency in the moment used by individual surgeons and all groups in the two tests

DISCUSSION

Although a manual test for long bone fracture stability is but one factor considered in the decision to discontinue external support, it is an important one When the injured bone is sufficiently mechanically stable for normal function the fracture is functionally healed It plays an equally important role in evaluating a possible non-union and in the decision to intervene surgically The roentgenogram provides a two dimensional representation of the situation and even with multiple views, the vagaries of fracture geometry may hide a pseudoarthrosis Decreasing local fracture tenderness and pain reflects the healing of injured tissue at the fracture site and is usually associated temporally with maturing callus However, the absence of pain does not necessarily indicate a healed fracture In fact, many non-unions are pain free The functional common denominator is stability

Mechanical stability of healing fractures was studied by Jernberger (1970) who applied a controlled bending moment directly to bone through pins *in vivo* in humans Interestingly, the threshold bending moment value he determined for the clinically stable tibial fracture is approximately 104 kgf cm if a 2 3 degree angulation is produced The values he was able to record with extensive instrumentation when fractures were functionally healed are remarkably similar to the values determined manually by our group of orthopaedic surgeons

CONCLUSIONS

These studies indicate that there is an appropriate bending moment force used by the majority of orthopaedic surgeons in testing for fracture stability Most surgeons appear to be able to sense a 2 3 degree angular deformation at the fracture site and tend to further immobilize fractures which bend to a greater degree There was an unexpected consistency in the bending moment utilized by each physician in the different tests and in the average moments for the different groups This would appear to indicate that the ability to appropriately

test healing fracture stability is easily learned by experience early in the orthopaedic residency

SUMMARY

An instrument simulating the feel of a fractured forearm was used to determine the average bending moment used by ninety orthopaedic surgeons in determining fracture stability The relative stiffness, bending moment, and associated angulation at the decision healed' were measured Remarkable consistency in these values was observed from test to test by each physician and between groups of orthopaedists selected according to experience

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FINGERTIP LESIONS
AN EVALUATION OF CONSERVATIVE TREATMENT VERSUS FREE SKIN GRAFTING

Axel Holm & Lis Zachariae

Accepted 5 ix 73

Lesions of the fingertips are very common injuries and the number seems to be rising, partly because of increasing mechanization and partly, at least in Denmark, because of the increasing number of foreign workers who do not pay sufficient attention to safety precautions or maybe do not understand them In 1961 Clarkson indicated that in the United Kingdom about 100,000 patients a year were treated in emergency rooms for lesions of one or more fingertips, and Constant writes that in 1966 17 per cent of the injuries reported to the insurance companies were made up of fingertip lesions

An injury to the tip of a finger is perhaps a small injury, but it is important, as the time of convalescence is often comparatively long and the patients may have great difficulty getting back to work again Constant (1971) indicates that the period of incapacitation varies from 10 108 days, always being a couple of weeks longer in insured cases than in the non-insured

The actual treatment depends, not only on the size and nature of the defect, but also on the patient's age and profession and not least on his mental habitus and in addition on the degree of specialization of the department in which he is treated

There are a variety of methods by which pulp lesions can be treated taking the above into consideration

1) Primary suture
2) Shortening of the finger with suturing of soft parts
3) Plastic surgical methods, either free skin grafting or various more complicated procedures
4) Conservative treatment

This last method which this paper is trying to illustrate, viz conservative treatment with spontaneous healing of the defect, is not highly regarded in the literature and several have actually warned against it

MATERIAL

In a five year period 107 patients with pulp lesions by which we mean lesions distal to the distal interphalangeal joint that do not include either flexor or extensor tendons but often nail and nailbed were treated in the emergency room at Gentofte Hospital

Table 1 Distribution according to sex age and treatment in 107 patients with fingertip lesions

	♂	♀	<15	15–30	31–50	>50
38 4) Conservative treatment	21 55%	17 45%	6	10	14	8
32 1) Primary suture	24 75%	8 25%	6	14	3	9
18 3) Transplantation of skin	14 78%	4 22%	8	7	0	3
19 2) Amputation	17 90%	2 10%	1	4	8	6

Table 2 Distribution according to type of lesion and treatment in 107 patients with fingertip lesions

	Lesion of soft tissue only	Lesion of soft tissue including nail and nailbed	Lesion of soft tissue and bone	Lesion of soft tissue nail and bone
38 4) Conservative	38	8	3	3
32 1) Primary suture	32	13	3	5
18 3) Transplantation of skin	18	9	4	4
19 2) Amputation	19	19	16	16

Table 3 Subjective complaints at follow up on 107 patients treated for fingertip lesions

	Subjective complaints							Results		
	Shortening	Coldness	Hypaesthesia	Paraesthesia	Hyperaesthesia	Tenderness	Stiffness	Good	Acceptable	Poor
38 pt Conservative treatment		15 39%	10 26%	0	1 3%	5 13%		34 90%	4 10%	
32 pt Primary suture		10 31%	12 38%	2 6%	2 6%	6 19%	3 9%	28 88%	4 13%	
18 pt Transplantation	2 16%	6 33%	12 67%	1 6%	1 6%	6 33%	3 17%	10 56%	6 33%	2 16%
19 pt Amputation	11 58%	15 79%	5 26%	5 26%	2 13%	8 42%	6 32%	9 47%	6 3-%	4 21%

Table 4 Objective findings at follow up on 107 patients treated for fingertip lesions

	Objective findings													
	Atrophy	Fissured skin	Adhered skin	Deficient nail	Indurated scar	Tenderness	Abnormal mobility of joints	Diminished touch	Hyp aesthesia	Hyper aesthesia	Diminished 2 point dis crimination	Diminished temperature feeling	Diminished stereognosis	Cyanosis
38 pt Conservative	1 2 6%	0	2 6%	5 13%	18 48%	2 6%	0	4 10%	5 13%	1 2 6%	3 8%	3 8%	0	0
32 pt Primary suture	2 6%	1 3%		4 13%	3 9%	1 3%	3 9%	6 19%	10 31%	3 9%	9 28%	8 25%	4 13%	0
18 pt Transplantation of skin	12 67%	10 56%	3 17%	11 6%	12 67%	0	6 33%	11 61%	12 67%	4 23%	12 67%	5 28%	5 28%	0
19 pt Amputation	2 11%	1 5 5%	2 11%	4 21%	0	5 26%	9 47%	3 17%	4 21%	9 47%	5 26%	2 11%	6 32%	0

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32 pt Primary suture		10 31%	12 38%	2 6%	2 6%	6 19%	3 9%	28 88%	4 13%	
18 pt Transplantation	2 16%	6 33%	12 67%	1 6%	1 6%	6 33%	3 17%	10 56%	6 33%	2 16%
19 pt Amputation	11 58%	15 79%	5 26%	5 26%	2 13%	8 42%	6 32%	9 47%	6 32%	4 21%





Figure 1 Sequels after fingertip lesion treated with grafting of a free intermediate thickness graft Note the angular shape the small annoying remains of the nail and the formation of skin fissures in the graft

Table 5 Duration of treatment in 107 patients with fingertip lesion

	4 weeks		4–8 weeks		8 weeks	
Conservative treatment	25	81%	6	19%		
Primary suture	14	61%	7	31%	2	9%
Transplantation of skin	4	57%	3	43%		
Amputation	5	33%	8	53%	2	13%

They have been followed up after an interval of 5–10 years Table 1 shows the distribution between men and women and the age distribution The types of lesion are indicated in Table 2 The following methods of treatment have been used Primary suture, shortening of the finger with suture, free skin grafting, or conservative treatment The latter is characterized by open wound treatment after removal of any protruding bone The wound is dressed with Fucidine gauze or some similar antibiotic preparation and is left to granulate and epithelialize spontaneously

At the follow up examination the patients have been thoroughly questioned as to any subjective complaints The results are indicated in Table 3 which also shows the patients' subjective impression of the final result of the various methods of treatment

The physical examination has been concentrated on the condition of the scar, the trophic condition, sensibility, function of the joints and the state of the finger as a whole The results are indicated in Table 4 The hands have been photographed and tested with the Ninhydrin test The duration of treatment is indicated in Table 5

DISCUSSION

The emergency service involved in this study is a large, general emergency service with about 100–120 cases per 24 hours It is attended by surgical house officers and only in rare cases has plastic surgery expertise been available Only recently a department of hand surgery has been established, this was not in operation when the patients included in this study were treated

The demands of a satisfactory treatment of fingertip injuries are

1) The length of the finger must be preserved as much as possible
2) The stump must be covered with good, non-tender soft tissue
3) The sensibility must be as normal as possible
4) There must be free movement of joints

Only the less complicated methods are considered in the present material and there are no plastic procedures like Kuttler's (Fischer 1967), Wesley Snow's method (1967), transplants of toetips (Marchac & Rousso 1971), V-Y plasty (Atasoy et al 1970) or the usage of ped-



Figure 3 Well healed intermediate thickness graft The Ninhydrin test shows no functioning sweat glands in the graft The next finger serves as control

Partial amputation with primary suture of soft parts results in shortening of the finger which was subjectively troublesome in 58 per cent of patients The stump of course is covered with a solid soft tissue cover and usually has good sensibility but it is often annoyingly tender This was found in 26 per cent while those conservatively treated are only tender in 6 per cent of cases and those grafted do not have this complaint at all The same observation has been made in other studies Bossen Moller et al (1961) find tenderness in 36 per cent of the partially amputated as compared to 21 per cent of those treated conservatively and 22 per cent of the grafted cases and in a material from 1963 Sturman & Duran find a similar tenderness in the partially amputated in 41 per cent They have no conservatively treated



Figure 2 Fingertip lesion treated conservatively Note the slightly indurated scar The Ninhydrin test shows absence of perspiration in the scar The same finger on the other hand serves as control

icled grafts from the palm or from other fingers as for instance indicated by Gottlieb & Mathiesen (1961), Flint & Harrison (1965) and Bennett (1966)

It is clear that the patient's age and the type of lesion is of importance for the selection of the method of treatment and its results, but the results here have been evaluated together as the groups otherwise would have been too small for evaluation, and it was felt that a compiled study of a mixed material from an unspecialized emergency service might be of interest

Primary suture gave good results, the subjective result being good in 88 per cent and there being no poor results, but this can only be carried out in feasible lesions



Figure 3 Well healed intermediate thickness graft The Ninhydrin test shows no functioning sweat glands in the graft The next finger serves as control

Partial amputation with primary suture of soft parts results in shortening of the finger which was subjectively troublesome in 58 per cent of patients The stump of course is covered with a solid soft tissue cover and usually has good sensibility, but it is often annoyingly tender This was found in 26 per cent while those conservatively treated are only tender in 6 per cent of cases and those grafted do not have this complaint at all The same observation has been made in other studies Bojsen-Møller et al (1961) find tenderness in 36 per cent of the partially amputated as compared to 21 per cent of those treated conservatively and 22 per cent of the grafted cases, and in a material from 1963 Sturman & Duran find a similar tenderness in the partially amputated in 41 per cent They have no conservatively treated

cases, but these authors also find tenderness in as large a number as 68–70 per cent of patients treated with primary free skin grafting

Free skin grafting preserves the length of the finger, but the stump often acquires a rather unbecoming square shape A further important complaint is indurated and fissured skin at the site of grafting (Figure 1). This was found in 67 per cent and just as many have decreased sensibility Similar findings have been made by Jakobsen & Kunov (1967) with Mandal's method and Mandal himself (1962) also mentions this without quoting any figures In reality Mandal's method only consists of a very meticulously executed free skin grafting with a thick intermediate graft (Mandal 1962, 1965, Jakobsen & Kunov 1967) It must be mentioned additionally that 66 per cent have complaints regarding the donor site on the forearm

The conservative treatment as carried out in the emergency room at Gentofte Hospital consists, as mentioned above, of covering the defect with Fucidine gauze and a compressive dressing, and changing this dressing on an ambulatory basis about every 5 days This method gives the longest possible finger stump with a rounded fingertip and good soft tissue covering (Figure 2) though with an indurated scar in 48 per cent and reduced sensibility in 13 per cent as compared to 67 per cent of the grafts The scar, however, is small (Figure 2) as the defect contracts during the spontaneous granulation and epithelialization and pulls skin and subcutaneous tissue with normal sensibility in from the surroundings

The conservatively treated only have few subjective complaints, mostly from cold However, these are no more pronounced than for the other methods of treatment The subjective results were good in 90 per cent of cases, and there were no poor results The second best results from a subjective point of view, 88 per cent good, were found in primary suture The graft cases were only good in 33 per cent and poor in 16 per cent and amputation gave 32 per cent good and 21 per cent poor results

The conservative treatment has not been mentioned much in the literature Boysen-Møller et al did a follow-up on such a series in 1961 and compared it with other methods They recommend the conservative treatment emphasizing that these patients get a cosmetically better, more rounded fingertip than those receiving free grafts, the sensibility is more normal, and an advantage compared with reamputation is that the stump is not tender

Atrophy of the finger stump in the present series was found in 67

per cent with grafts 11 per cent with amputations, 6 per cent with primary suture and only 2 6 per cent with conservative treatment

Nail changes were rather evenly distributed throughout the series and obviously depended on the site of the lesion If the patient later developed symptoms from the nail, the authors have carried out excision of the residual nail and nailbed with application of a full thickness graft

Changes in the sensibility were found in a very large number of patients Thus, in grafted patients sensibility was reduced in 67 per cent, in primary suture patients in 31 per cent, in amputation patients in 21 per cent and in 10 per cent of those treated conservatively Hypersensibility was found in 23 per cent of grafts, 9 per cent of primary sutures 47 per cent of amputations and 2 6 per cent of those conservatively treated

The Ninhydrin test shows changes in the scar itself and in the grafts (Figure 2 and Figure 3) which speaks in favour of choosing that procedure which is liable to give the smallest scar or graft respectively

Permanent reduction of joint mobility was found in 28 per cent of the grafted patients in 13 per cent of the primary suture patients, in 32 per cent of amputation patients and in none of the patients with conservative treatment This is dependent on the duration of immobilization and could probably be reduced

CONCLUSION

On the basis of the present study and the results of others it can be concluded that fingertip injuries if treated in an ordinary emergency room without plastic surgical expertise, in most cases are best treated with a conservative regime if primary suture cannot be carried out Partial amputation gives shortening and tenderness grafts give trouble from the scar and reduced sensibility while conservative treatment preserves finger length, gives good, round stumps with small scars and good sensibility

Furthermore conservative treatment gives fewer complications as regards joint function and has the shortest duration of treatment

SUMMARY

107 patients with fingertip injuries have been followed up after 5 10 years The following principles of treatment were used 1) primary

suture, 2) partial amputation and suture, 3) free skin grafts 4) conservative treatment

It is concluded from the results and comparison with the work of others that conservative treatment gives subjectively good results in 90 per cent of cases and no poor results

The results of primary suture are equally good and this should be carried out if possible The most important complaints after partial amputation are shortening and tenderness, and after grafting, induration and fissuring of the skin and reduced sensibility of the graft as well as complaints from the donor site

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PARTIAL ANTERIOR RESECTION OF THE PELVIS

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In 1962 we attended a female patient who had a large chondrosarcoma of the left ischio-pubic ramus which formed a protrusion within the vulva This same mass had prevented the normal birth of a child by obstructing the lumen of the pelvic ring besides causing both pain and problems on micturition The roentgenographic image was almost completely pathognomonic of chondrosarcoma

Since the patient was a 24 year old female, it was decided that surgery was the indicated means of treatment Diagnosis was confirmed by means of a biopsy

It was decided after careful study of the regional anatomy, that the technique earlier reported by Milch (1949) would be the most appropriate and adaptable to our needs Some doubts remained as to the outcome of the surgical resection of a section of the pelvic girdle since Steindler (1955) had stated that The bones are fixed within the pelvic girdle under considerable elastic tension if this intrinsic equilibrium is destroyed by resecting one part it will spring out in a manner very similar to the thoracic cavity Besides the antecedent existed whereby obstetricians had attempted to solve the problem of a narrow pelvis by making parallel cuts on either side of the symphysis pubis with a Gigli saw The procedure was apparently abandoned because of resultant pain and the appearance of a waddling gait Therefore it was decided that a large tibial graft be used to buttress the pelvis fixing it in place with screws thus avoiding pelvic spreading and alterations in gait

Surgery proved to be more difficult than had been expected and we were unable to remove the tumor as a whole The mass had to be sectioned in order to remove the posterior portion The surgical procedure was not prolonged to include the planned graft which would be done at another time after satisfactory recovery Post-operative

suture, 2) partial amputation and suture 3) free skin grafts, 4) conservative treatment

It is concluded from the results and comparison with the work of others that conservative treatment gives subjectively good results in 90 per cent of cases and no poor results

The results of primary suture are equally good and this should be carried out if possible The most important complaints after partial amputation are shortening and tenderness and after grafting induration and fissuring of the skin and reduced sensibility of the graft as well as complaints from the donor site

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Figure 1 Very large calcified irregular mass inserted in the pelvic ring which has apparently invaded the coxofemoral joint



Figure 2 Notice the absence of the ischio pubic ramus

As in the preceding case it proved impossible to dissect or mobilize the posterior portion of the tumor and the mass had to be sectioned in order to be able to resect this part

The histological study proved the tumor to be a chondrosarcoma.

Post operative evolution was satisfactory and the patient was followed up by means of periodic consultations for a period of six months (Figure 2)

At this point she stopped coming and did not reappear until October 1970 During this interval she had become pregnant again and normal delivery had taken place at the end of 1969 Since then she had noticed that a tumor was once again growing in the area of the old scar

X rays again showed a large calcified mass (Figure 3) Chest X rays did not reveal any metastatic lesion

evolution was uneventful, except to mention that one week after surgery the patient initiated deambulation without claudication or pain

In this way, we learned that it is possible to excise a large fragment of the pelvic girdle, anteriorly, interrupting its normal continuity, without producing either an alteration in biomechanics or pain and/or instability upon deambulation and without producing alterations in pelvic weightbearing during pregnancy or labor. Later treatment of two similar cases has confirmed our point of view. No special emphasis is made as to the onchological aspects of these patients since that is not the purpose of this paper, nor would we have anything new to add on the evolution of chondrosarcomas, and it is a well-known fact that local recurrences frequently occur.

CLINICAL CASES

G P M File No 42413, National Institute of Cancerology The main clinical data have practically all been exposed in the introduction and it will be only necessary to add that the patient returned 14 months later and reported that she had been leading a normal life and had become pregnant once again Childbirth had been normal After the birth of the child she had once again noticed a tumorous swelling that had been growing slowly, and this was the reason for her visit at this time She was also suffering from urinary incontinence A new tumor, larger than the first was found X-rays once again showed a large calcified mass occupying part of the space left by the resection A new operation was performed in June, 1964 Upon completion of the extirpation of the tumor which left a large cavity, due to the fact that on this occasion the tumorous mass had invaded part of the peritoneum, the patient fell into shock and all efforts to save her life proved unsuccessful

G R F File No 54574 National Institute of Cancerology. Female aged 25, who came for consultation in March, 1967, due to a tumor that had appeared 4 years previously in the upper portion of the left thigh, and which had been operated on twice, but nevertheless continued to grow She had 3 children, the youngest born six months previously Upon examination the patient was found to be underweight and was reluctant to cooperate due to her low level of intelligence Pertinent data encountered included presence of a tumorous mass, plainly visible in the lower part of the abdomen, more or less rounded and about 30 cm in diameter, occupying the left flank the inguinal region and the upper part of the left thigh In the middle of the mass, following the inguinal fold, there was a scar approximately 15 cm long The coxofemoral joint moved freely (Figure 1)

An operation was performed on April 5, 1967, and the tumor was extirpated following the technique reported by Radley et al (1954), modified to fit the needs of the case by extending the incision outwards following the inguinal fold It should be noted that during the operation the vessels were found to have been rejected by the mass and it was necessary to dissect them in order to free them



Figure 1 Very large calcified irregular mass, inserted in the pelvic ring, which has apparently invaded the coxofemoral joint



Figure 2 Notice the absence of the ischio pubic ramus

As in the preceding case, it proved impossible to dissect or mobilize the posterior portion of the tumor, and the mass had to be sectioned in order to be able to resect this part.

The histological study proved the tumor to be a chondrosarcoma.

Post operative evolution was satisfactory and the patient was followed up by means of periodic consultations for a period of six months (Figure 2)

At this point she stopped coming and did not reappear until October 1970 During this interval she had become pregnant again and normal delivery had taken place at the end of 1969 Since then she had noticed that a tumor was once again growing in the area of the old scar

X rays again showed a large calcified mass (Figure 3) Chest X rays did not reveal any metastatic lesion



Figure 3 Recurrence of the chondrosarcoma

Another operation was performed on October 28 1970 The vessels and the crural nerve were found invaded by the tumor The nerve was freed and on attempting to dissect the artery a tear occurred which necessitated ligation below its juncture with the circumflex and deep femoral arteries which were hypertrophic Circulation in the foot was maintained in good condition

The wound was closed and a further operation was planned in order to resect the tumor and do a bypass of the femoral artery or a teflon implant graft

The patient refused to consent to this operation and has made no further visits for consultation

B L V Consultation file 4935 (Private office L Z) Female aged 22 single a bank employee who works standing and came for consultation because she had noticed pain in the right groin that had been steadily increasing for the previous 2 months She had also noticed a growth in the same spot Physical examination showed a well nourished person with a hard tumorous mass in the right groin causing increased volume of the right labium majus X rays showed a calcified mass implanted in the right ischiopubic ramus that was diagnosed as chondrosarcoma

An operation was performed on July 30 1970 and the tumor was extirpated following the Radley technique (1954) It should be noted that in this case also mobilization of the posterior portion of the mass without resection of the rest of the tumor proved impossible once again preventing extirpation of the tumor as a whole

The patient returned to her usual activities three months after operation and has continued until now without discomfort The latest clinical and radiological examination was made January 10 1973 No abnormal data were found and she leads a normal life

DISCUSSION

In reviewing the literature on this subject we find on the one hand Steindler's (1955) previously mentioned statement The bones are

fixed within the pelvic girdle under considerable elastic tension, if this intrinsic equilibrium is destroyed by resecting a piece, it will spring out in a manner very similar to the thoracic cavity " (Page 201, paragraph 4) On the other hand there is the fact that those who have reported on extirpation of the ischium generally do not mention the post-operative behaviour of the patient as far as gait is concerned, nor the extent of the resection effected

In Byers' article (1963) it can be seen that the resection was minimal, taking in only a portion of the ischium itself without affecting the roof of the obturator foramen This resection could by no means be expected to alter pelvic mechanics or the patient s gait, since it did not affect the interior contour of the pelvic ring

We believe that, on the basis of the three cases reported here, it is possible to prove that integrity of the pelvic ring is not indispensable for gait stability since, in these patients, it has not been affected in spite of ample resections

On the other hand, we believe that the pain and lack of stability reported in the past is a consequence of the parasymphyseal osteotomies performed by obstetricians, due to the fact that these interventions produced a pseudoarthrosis that might possibly have been avoided had a resection been performed

It is quite possible that stability may be achieved in cases like ours through the posterior ligaments of the pelvis and the integrity of the sacroiliac joint since as Steindler (1955) mentions, Putschar points out that in cases of congenital absence of the anterior portion of the pelvic girdle hypertrophy of the posterior osseous portion and of the ligaments is observed

From the technical viewpoint insofar as the onchological aspects of these cases are concerned it should be mentioned that a common factor in all three cases, which may possibly play an important role in the recurrences of the tumor is that the posterior portion of such tumors is difficult if not impossible, to mobilize, and in all three cases it was necessary to section the greater anterior mass, before removing this posterior portion

We believe that our study of these cases, however brief, opens the way for a study of pelvic mechanics, through the results obtained from necessary surgery In the future it may be possible to change some of the concepts we have followed for many years

CONCLUSIONS

A useful conclusion that may be reached from these experiences is that interruption of the continuity of the pelvic girdle in its anterior portion even when the resection is ample does not produce alterations in gait or in the mechanics of pregnancy or childbirth

SUMMARY

Presentation is made of 3 cases of chondrosarcomas implanted in the ischiopubis ramus and treated by partial anterior resections of the pelvic girdle The patients treated in this manner were able to walk without pain or instability and two of them became pregnant after surgical intervention with no obstetrical problems

In two cases there were recurrences of the tumor

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COXA VARA FOLLOWING IMMOBILIZATION OF THE KNEE IN EXTENSION IN YOUNG RABBITS

JARL-ERIK MICHELSSON & ANDERS LANGENSKIÖLD

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In a previous paper (Michelsson & Langenskiold 1972) we reported that after a sufficiently long immobilization (more than three weeks) of one hind limb with only the knee in extension, but the hip free and flexible, in young rabbits (less than three weeks old), a dislocation or subluxation of the hip developed as a rule on the immobilized side However after discission of the hamstring muscles and a subsequent immobilization of the knee in extension no marked changes in the hip developed Other dysplastic changes also developed in the experimental animals in connection with the immobilization of the knee in extension i e coxa plana and coxa vara In this paper we shall refer especially to the pathological condition of the hip in which the angle between the shaft and the neck of the femur diminished This phenomenon, coxa vara developed in many of the older animals (aged more than three weeks at the beginning of immobilization) in the investigations regarding the effect of the immobilization on the joints of growing rabbits

MATERIAL AND METHODS

For these investigations seventy growing rabbits (two to twelve weeks old) were used One of the hind limbs was immobilized with the knee in extension but with the hip free to move The immobilization was accomplished either by a plastic tube fixed proximally to the skin of the femur (sixty two rabbits) or by a metal pin applied dorsally in the soft tissues of the limb (eight rabbits) These methods have been more fully described in another of our papers (Michelsson & Langenskiöld 1972)

In another twenty five growing rabbits the hamstring muscles were cut proximally or distally just before the immobilization of the knee in extension of the same limb was performed

Table 1. Final results in seventy young rabbits following immobilization of one hind limb with the knee in extension (cf. Figures 1, 2 and 3)

Age of rabbit in weeks at the beginning of immobilization	Duration of immobilization in weeks			Coxa vara on the immobilized side				Other changes of the hip on the immobilized side		No deformity of the hip	Total
	Shortest	Longest	Average	C.V. only	C.V. and subluxation	C.V. and dislocation	Total C.V.	Dislocation	Subluxation		
2	3	4	3.3	–	–	2	2	1	–	–	3
3	3	4	3.7	2	1	2	5	2	–	–	7
4	3	4	3.4	13	5	7	25	5	–	–	30
5	3	6	4.1	2	2	2	6	1	2	–	9
6	3	8	4.4	4	1	2	7	–	1	–	8
8	4	5	4.3	–	1	–	1	–	1	1	3
10	4	6	4.5	3	–	–	3	–	–	3	6
12	3	4	3.7	1		–	1	–	–	3	4
Total				25	10	15	50	9	4	7	70

The immobilization of the knee was stopped by the removal of the plastic tube after at least three weeks usually after three to four weeks but in some cases up to eight weeks (cf Table 1)

During the immobilization of the knee the rabbit kept the hip of the immobilized side in normal flexion in a sitting and resting position

The condition of the hips was recorded radiographically at regular intervals after the procedures in some cases to adult age

The hips of twenty five of these rabbits were prepared for micro and macroscopic investigations

RESULTS

Of the seventy rabbits that had the knee of one hind limb immobilized in extension, sixty three had some abnormality of the hip whereas seven had no permanent changes (Table 1) These abnormalities have been defined on the basis of radiological and pathologic anatomical findings as coxa vara, dislocation and subluxation By coxa vara we mean a condition whereby the angle between the neck and the shaft of the femur is diminished

Twenty five of these seventy five rabbits had coxa vara only (Figure 1) ten had coxa vara and subluxation of the hip (Figure 2), fifteen coxa vara and dislocation of the hip (Figure 3), nine dislocation only and four subluxation of the hip only

Marked pathological changes of the hip including coxa vara occurred most frequently in those rabbits that were three to six weeks old when the immobilization was begun. Of the fifty-four rabbits in these age groups twenty one had coxa vara only and twenty-two coxa vara and dislocation or subluxation of the hip on the immobilized side In the oldest rabbits (eight to twelve weeks old) usually no changes or only slight ones developed in the hip of the immobilized limb

These experiments showed that the development of the changes in the hip were dependent upon the age of the rabbit when the immobilization was begun The younger the animal was the more frequent was the development of serious and permanent pathological changes in the hip Progression of the coxa vara deformity and a pathological position of the head of the femur (dislocation or subluxation) usually developed after sufficiently long immobilization, gradually and simultaneously during the period of growth (cf Figures 1, 2 and 3)

In the experimental coxa vara it was possible to find not only a diminishing of the angle between the femur and the neck of the femur, but also the following pathological changes in both the acetabulum and

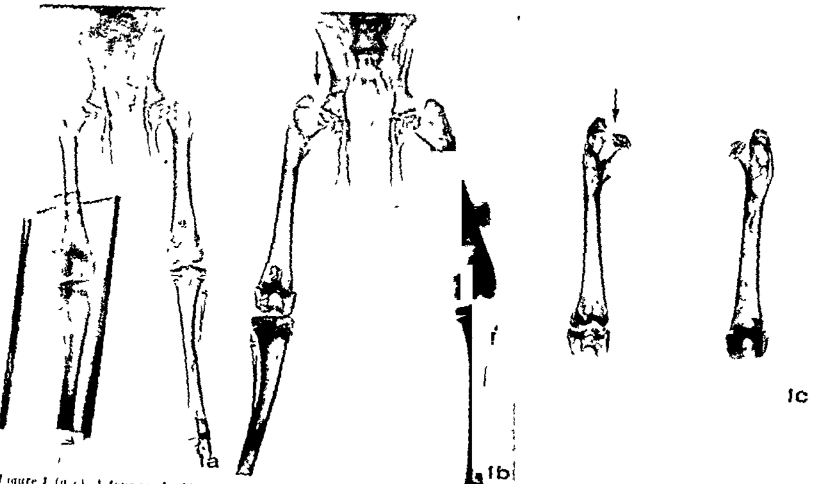


Figure 1 (a–c). A four week old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension. Two weeks after the procedure a slight coxa vara was visible on the right side (Figure 1a). The plastic tube was removed 3 weeks after the procedure. A progressive coxa vara deformity was observed 6 weeks after the procedure (Figure 1b). The femurs one week later (Figure 1c).



Figure 2 (a–c). A four week-old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension. Two weeks after the procedure subluxation of the right hip was observed (Figure 2a) and two weeks later subluxation and a slight coxa vara deformity had developed (Figure 2b). The plastic tube was then removed. Four months after the immobilization was started subluxation and marked coxa vara were visible (Figure 2c).

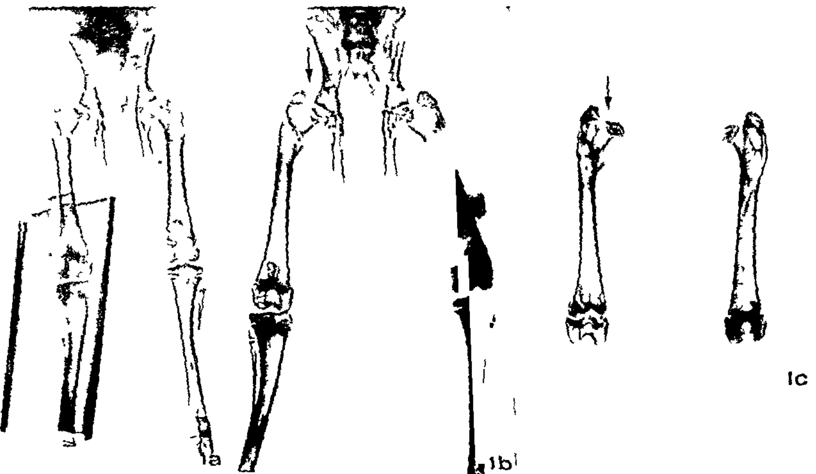


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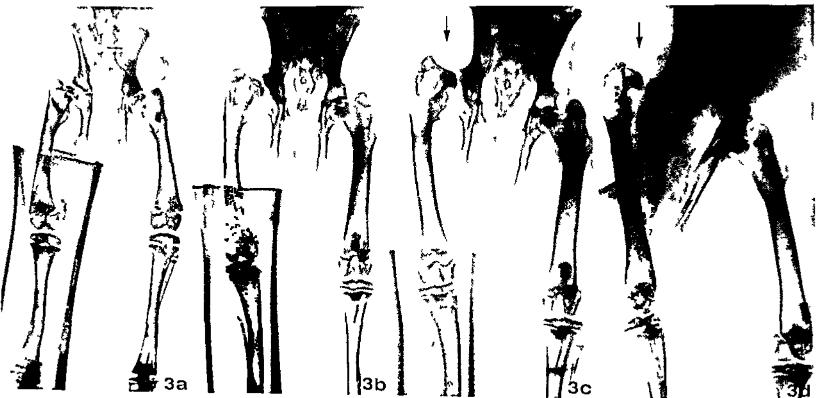


Figure 3 (a–d) A three week old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension One week after the procedure subluxation of the right hip was observed (Figure 3a), two weeks (Figure 3b) and six weeks later (Figure 3 c) a progressive coxa vara deformity also developed Three months after the procedure dislocation and coxa vara were observed (Figure 3 d)



Fig 4 a



Fig 4–a_1



Fig 4 b

retroversion

normal anteversion



Fig 4–b_1





Fig 4–c *Fig 4–c₁*

Figure 4 (a–c) Specimens of the proximal ends of the femurs of a rabbit This four-week old animal was immobilized with the right hind limb in extension for three weeks and killed three months after the immobilization was started In the right hip (a b and c) a coxa vara deformity including a retroversion of the head and neck of the femur were observed but the left hip (a_1, b_1 and c_1) was normal (the head and neck of the femur were in a normal, anteversion position)

all parts of the proximal end of the femur (c f Figures 1, 2, 3, 4, 5 and 6)

- The acetabulum was often deformed in outline and more shallow than normal
- The head of the femur was often lower and broader and situated more posteriorly and inferiorly than normal
- The epiphyseal plate of the head of the femur was in some cases more vertical than normal
- The neck of the femur was usually shorter than normal and retroverted compared with the normal
- The greater trochanter was situated more cranially than normal and the superior part of it was often bowed medially
- The lesser trochanter was often situated nearer the head of the femur than normal
- The ossification centres of the femoral head and the greater trochant-



Figure 5 (a b) A four week old rabbit was immobilized with the right knee in extension Three weeks later a coxa vara deformity was observed on the right side (Figure 5a) but the left hip was normal (Figure 5b)

er were joined by a bridge of bone in some rabbits with coxa vara (Figure 6)

The proximal end of the femur was often bowed medially and on its medial side more sclerosis than normal was visible

The movement of the hip was usually decreased especially abduction and rotation

All these pathological findings are described similarly in human coxa vara Amstutz & Wilson 1962 Blockey 1969 Marchetti & Faldini 1968 Lykkeneen 1960)

DISCUSSION

Both the aetiology and pathogenesis in many of the most common diseases of the hip in childhood i e coxa vara coxa valga coxa plana and congenital dislocation of the hip are rather obscure It is known that coxa vara may develop in children after fractures or infection of the hip and after treatment of dislocation of the hip but in most cases of





Fig. 4–c *Fig. 4–c_1*

Figure 4 (a–c). Specimens of the proximal ends of the femurs of a rabbit. This four-week old animal was immobilized with the right hind limb in extension for three weeks and killed three months after the immobilization was started. In the right hip (a, b and c) a coxa vara deformity including a retroversion of the head and neck of the femur were observed but the left hip (a_1, b_1 and c_1) was normal (the head and neck of the femur were in a normal, anteversion position).

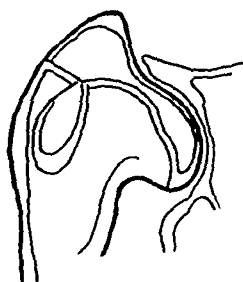
all parts of the proximal end of the femur (c.f. Figures 1, 2, 3, 4, 5 and 6).

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- The lesser trochanter was often situated nearer the head of the femur than normal.
- The ossification centres of the femoral head and the greater trochant-

coxa vara the aetiology is unknown (Amstutz & Wilson 1962, Pylkkänen 1960) Many theories have been formulated to explain the development of both the infantile and adolescent forms of coxa vara and these are based on clinical and radiographical investigations Among other possible aetiological factors, traumata, infections, rickets, vascular disturbances and mechanical changes have been proposed These theories are reported for instance in a thesis of Pylkkanen (1960) Previously many experimental investigations have been made to clarify the pathogenesis of coxa vara After destruction of the epiphyseal plate of the head of the femur in growing animals, coxa vara often developed (Burckhardt 1948, Compere et al 1940, Nagura & Kosuge 1938 Nagura 1940 Salenius & Videman 1970) Following destruction of the epiphyseal plate of the greater trochanter, coxa valga has developed (Compere et al 1940 Langenskiold & Salenius 1967, Laurent 1959) and this method has been used in the treatment of some forms of coxa vara (Langenskiold & Salenius 1967, Pylkkanen 1960) The above mentioned methods of provoking coxa vara have all been traumatic In our experiments we have induced deformities of the hip e g coxa vara without any direct trauma to the hip but instead created a muscular imbalance of the hip by the immobilization of the knee in extension The immobilization of the knee in extension led to an increased tension on the hamstring muscles when the animal kept the hip in flexion Therefore we cut the hamstring muscles in twenty five animals and thereafter the same limb was immobilized with the knee in extension None of these animals developed any marked coxa vara or other dysplastic changes of the hip which shows that the increased tension of the hamstring muscles played an essential role in the development of coxa vara and dislocation of the hip in our experiments (Michelsson & Langenskiold 1972) The experimental coxa vara proved to have similar pathological features as are described in human coxa vara A regression of the pathological changes in the hip was noticed in some animals especially after a short period of immobilization In some cases of human coxa vara the pathological changes have disappeared especially *if the child has been kept at rest* (Lindemann 1941 1949 Pylkkanen 1960 Rettig et al 1970) These facts and other experimental evidence support the theory that as in our experiments mechanical factors affecting the growth of the capital epiphyseal plate play an important role and may also be essential factors in the development of the human coxa vara

The therapy is usually also directed towards changing the loading





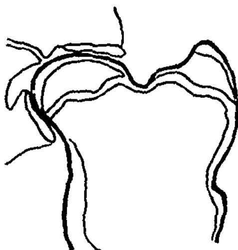


Figure 6 (a–d). A six week old rabbit was immobilized with the knee of the right hind limb in extension. One month after the procedure the animal was killed. In the sections a coxa vara deformity and a bony fusion between the ossification centres of the femoral head and the greater trochanter were observed in the right hip (Figure 6a), but the left hip was normal (Figure 6b). Figure 6c. Explanatory drawing of the section in Figure 6 a. Figure 6 d. Explanatory drawing of the section in Figure 6b.

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forces of the hip by osteotomy, and many cases of infantile coxa vara have developed more normally after osteotomy (Pylkkanen 1960)

The type of coxa vara seen in our experiments is very similar to that seen in connection with coxa plana or as a complication following *treatment of congenital dislocation* of the hip

These experiments show that both a coxa vara deformity and a dislocation of the hip may develop as a result of mechanical factors, a change of the forces normally acting on the hip The pathological changes of the skeleton may be explained by the laws of Wolff and Hueter-Volkmann regarding the transformation of cartilage and bone in relation to the forces acting upon these tissues

SUMMARY

In seventy growing rabbits, two to twelve weeks old, one of the hind limbs was immobilized with the knee in extension but with the hip free and able to be flexed In fifty of the rabbits a coxa vara deformity developed and in twenty-five of these subluxation or dislocation of the hip occurred in addition to coxa vara (c f Table 1) These phenomena of experimental dislocation and subluxation were described in a former article (Michelsson & Langenskiold 1972) *The coxa vara deformity* in our experiments was connected with similar features as are described in human coxa vara of different aetiology Both the acetabulum and the proximal end of the femur were deformed and the head and the neck of the femur were usually retroverted

The experiments show that in growing rabbits an atraumatically provoked change of the forces acting on the hip may lead to growth disturbance *of the capital epiphyseal plate and progressive* coxa vara

The similarity in the experimental and the human coxa vara justify our thinking that the infantile human coxa vara may also develop as an adaptive result of a change in the forces acting on the hip, which may, for instance, be provoked by a long lasting change of the position of the hip or knee

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forces of the hip by osteotomy, and many cases of infantile coxa vara have developed more normally after osteotomy (Pylkkanen 1960)

The type of coxa vara seen in our experiments is very similar to that seen *in connection with coxa plana* or as a complication following treatment of congenital dislocation of the hip

These experiments show that both a coxa vara deformity and a dislocation of the hip may develop as a result of mechanical factors, a change of the forces normally acting on the hip The pathological changes of the skeleton may be explained by the laws of Wolff and Hueter-Volkmann regarding the transformation of cartilage and bone *in relation to the forces acting upon these tissues*

SUMMARY

In seventy growing rabbits, two to twelve weeks old, one of the hind limbs was immobilized with the knee in extension but with the hip free and able to be flexed In fifty of the rabbits a coxa vara deformity developed and in twenty five of these subluxation or dislocation of the hip occurred in addition to coxa vara (c f Table 1) These phenomena of experimental dislocation and subluxation were described in a former article (Michelsson & Langenskiold 1972) The coxa vara deformity in our experiments was connected with similar features as are described in human coxa vara of different aetiology Both the acetabulum and the proximal end of the femur were deformed and the head and the neck of the femur were usually retroverted

The experiments show that in growing rabbits an atraumatically provoked change of the forces acting on the hip may lead to growth disturbance of the capital epiphyseal plate and progressive coxa vara

The similarity in the experimental and the human coxa vara justify our thinking that the infantile human coxa vara may also develop as an adaptive result of a change in the forces acting on the hip, which may, for instance, be provoked by a long-lasting change of the position of the hip or knee

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performing active exercises under the supervision of a physiotherapist whilst at other times moving the limb as much as possible After 10 days for total hip replacements and 17 days for femoral osteotomies the splints were removed and sling exercises commenced in bed Walking with crutches began 14 days after total hip replacement and 20 days after femoral osteotomy

One closed suction drain of the Redivac type was placed deeply in all the wounds and remained for 48 hours after operation

Warfarin 15 mg was given commencing at 8 00 a m on the second post operative day The prothrombin time was monitored daily and maintained between 20 per cent and 30 per cent by varying the Warfarin dosage This range was based on the work of Sevitt & Gallagher (1959), Moschos et al (1964) and Harris et al. (1967) Prothrombin levels above 35 per cent or fluctuating between 20 per cent and 50 per cent were considered to indicate inadequate anticoagulation The over administration of Warfarin led occasionally to levels well below 15 per cent Warfarin therapy was continued until the patients were fully ambulant which was on the average 21 days for total hip replacement and 28 days for femoral osteotomies Thus 4 groups of patients emerged and were classed according to the prothrombin times as therapeutic inadequate low and excluded (Table 1)

Table 1 Adequacy of anticoagulation

	Anticoagulation	Prothrombin time	Number of patients	Percentage
Group 1	Therapeutic	20–30 per cent	169	49
Group 2	Inadequate	35 per cent	79	23
Group 3	Low	15 per cent	12	3
Group 4	Excluded		86	25

Diagnosis of Deep Venous Thrombosis

A deep venous thrombosis was considered to have occurred when there was pain felt in the calf together with tenderness on palpation and tenderness along the line of the deep veins compared with the opposite calf The diagnosis was more certain if there was oedema of the lower leg and ankle dilated superficial veins in the lower leg and foot and a positive Homan's sign The diagnosis of pulmonary embolism was based on pleuritic pain, haemoptysis and occasionally dyspnoea together with the characteristic radiographic appearances and electrocardiographic changes

RESULTS

Adequacy of Anticoagulation

One hundred and sixty nine patients (49 per cent) received anticoagulants in therapeutic dosage (Table 1) Seventy-nine patients (23 per cent) received inadequate doses of anticoagulant resulting in a

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THE VALUE OF PROPHYLACTIC ANTICOAGULANT THERAPY WITH WARFARIN AFTER HIP SURGERY

D S Muckle, H J. Forney & George Bentley

Accepted 18 ix 73

The value of prophylactic anticoagulant therapy after surgery has remained in dispute following the report by Pinto (1970) who showed a similar incidence of deep-vein thrombosis in both treated and control groups, figures that refuted the earlier reports of Sevitt & Gallagher (1959), Salzman et al (1966) and Harris et al (1967)

Between January 1968 and December 1971 all patients undergoing total hip replacement and femoral osteotomy were considered for Warfarin therapy post operatively, and the effects of therapy on thromboembolic phenomena were observed At the same time the incidence of wound haematomata and systemic bleeding complications was recorded Thus the merits and complications of anticoagulation therapy could be assessed in a prospective manner Reliance was placed at the outset on the clinical diagnosis of deep-vein thrombosis and pulmonary embolism, whilst it is recognised now that thereby an underestimation of the frequency of venous thrombotic episodes is common (Kakkar et al 1969)

PATIENTS AND METHODS

Three hundred and forty six patients had undergone 112 McKee Farrar total hip replacements 97 Charnley total hip replacements and 137 femoral osteotomies There were 230 females and 116 males a ratio of 2 1 Ages varied from 52 to 84 with an average of 68 years The majority of patients (70 per cent) were over 60 years of age

Post operative Programme

At the end of the operation the limb was placed on a Hodgen s splint and active contraction of hip knee and ankle muscles was encouraged on recovery of consciousness Thereafter the patients spent 1 hour in each morning and afternoon

There was a slightly increased percentage of deep venous thrombosis in patients who had undergone femoral osteotomy but the differences were not statistically significant (Table 3)

Pulmonary embolism Ten patients (3 4 per cent overall) developed pulmonary emboli and one who was in group 4 died (Table 2) Deep venous thrombosis was diagnosed prior to pulmonary embolism in 6 cases (60 per cent) It is notable that none of the pulmonary emboli occurred in patients who were adequately anticoagulated (group 1) However, 7 patients (8 7 per cent) with pulmonary emboli had received anticoagulants in inadequate dosage (group 2) The remaining 3 cases (3 4 *per cent*) of pulmonary embolism occurred in the non-treated group (group 4) The differences between groups 1 and 2 and groups 1 and 4 and between groups 3 and 2 and 3 and 4 were *significant* ($P <$ 0 05)

Complications of Therapy—Bleeding Episodes

Wound haematomata Forty-two patients (12 *per cent* overall) developed a wound haematoma Seven were large (2 per cent) and required evacuation under general anaesthesia and transfusion of 3 pints of blood The remaining 38 (10 per cent) were small and healed spontaneously (Table 4) The incidence of wound haematoma was 13 per cent overall in 260 patients who received Warfarin (groups 1, 2 and 3) compared with 10 per cent in the non treated groups of 86 patients However, there was the same incidence (9 per cent) in patients treated with adequate doses of Warfarin (group 1) and those not receiving Warfarin (group 4) The highest percentage of haematomata, 21 per cent occurred in patients who were receiving inadequate doses of Warfarin (group 2) The reason for this is not obvious The differences between groups 1 and 2 and groups 2 and 4 are significant ($P < 0\ 05$) but that between groups 2 and 3 is not

All the wounds which developed haematomata healed and were not complicated by sepsis

Table 4 Incidence of wound haematoma.

	Group 1 (20–30 %)	Group 2 (35 %)	Group 3 (15 %)	Group 4 (Nil)
Patients	169	79	12	86
Haematoma	15	17	2	8
Percentage	9%	21%	17%	9%

prothrombin level above 35 per cent, and in 12 patients (3 per cent) the dose given produced a prothrombin level which was too low In 86 patients (25 per cent) Warfarin was withheld because the patients had some medical condition which made administration of Warfarin hazardous These contra indications were history of.

1 Dyspepsia, peptic ulcer or haemoptysis
2 Blood dyscrasia or purpura
3 Cerebro-vascular accident
4 Haematuria or recurrent cystitis
5 Gastro-intestinal or renal carcinoma

Thrombo-embolic Episodes

Deep venous thrombosis Through the series deep venous thrombosis was diagnosed only 19 times (6 per cent overall) In group 1 with adequate anticoagulation, only 1 of 169 patients (0.6 per cent) developed signs of deep venous thrombosis (Table 2) In group 2, where the prothrombin level was too high, 8 patients out of 79 (10 per cent) developed deep venous thrombosis which was comparable with the 10 cases out of 86 (11.6 per cent) in the untreated patients in group 4 Deep venous thrombosis did not occur in group 3 where the prothrombin level was too low The differences between groups 1 and 2, groups 1 and 4 and between groups 3 and 2 and 3 and 4 were significant ($P < 0.05$)

Table 2 Incidence of thrombo embolism

	Group 1	Group 2	Group 3	Group 4
Prothrombin time	(20–30 %)	(35 %)	(15 %)	(not given)
Patients	169	79	12	86
Deep venous thrombosis	1 (0.6 %)	8 (10 %)	0	10 (11.6 %)
Pulmonary embolism	0	7 (8.7 %)	0	3 (3.4 %)

Table 3 Thromboembolic episodes following different procedures

	McKee Farrar	Charnley	Femoral osteotomy
Pulmonary embolism	3 (2.7 %)	2 (2 %)	5 (3.6 %)
Deep venous thrombosis	4 (3.5 %)	5 (5.2 %)	10 (7.3 %)
Average period of bed rest (days)	14.6	14.8	20

There was a slightly increased percentage of deep venous thrombosis in patients who had undergone femoral osteotomy but the differences were not statistically significant (Table 3)

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Table 3 Thromboembolic episodes following different procedures

	McKee Farrar	Charnley	Femoral osteotomy
Pulmonary embolism	3 (2 7 %)	2 2 %	5 (3 6 %)
Deep venous thrombosis	4 (3 5 %)	5 (5 2 %)	10 (7.3 %)
Average period of bed rest (days)	14 6	14 8	20

effect of Warfarin in preventing clinical deep venous thrombosis is difficult to explain. It is probable that Warfarin prevents extension of the thrombus so that it rarely becomes extensive enough to produce clinical signs. This same mechanism might explain its more certainly established effect of preventing pulmonary embolism. This latter effect is, we consider, the most powerful argument for its use.

Table 6. Incidence of thromboembolism reported following hip surgery

Author		Incidence of thromboembolism	
		Control	Treated
Sevitt & Gallagher	(1959)	29.0%	2.7%
Neu et al.	(1965)	10.0%	0 %
Salzman et al.	(1966)	27.0%	7.0%
Harris et al.	(1967)	34.0%	7.0%
Pinto	(1970)	36.0%	32.0%

Diagnosis of Deep Venous Thrombosis and Pulmonary Embolism

The recorded incidence of deep venous thrombosis and pulmonary emboli varies from series to series according to the method of diagnosis used. Charnley (1972) in a series of 201 hip arthroplasties reported a clinical incidence of deep venous thrombosis of only 3 per cent and 3.2 per cent for pulmonary embolism. The limitations of clinical signs as an indication of venous thrombosis are now well recognised and Kemble (1971) recorded an underestimation of 50 per cent when he checked clinical diagnosis against the 125I labelled fibrinogen method. This agrees with the findings of Sevitt & Gallagher who in 1961 showed that of patients with deep venous thrombosis at post mortem only 1/3 were diagnosed clinically during life.

Silent Thrombosis

The importance of "silent" thrombosis in the pathogenesis of pulmonary emboli has rightly been given emphasis in the literature although Sevitt & Gallagher (1961) reported a greater incidence of fatal pulmonary emboli when a previous clinical diagnosis of deep venous thrombosis had been made. In this series 6 out of 10 pulmonary emboli were associated with a prior diagnosis of deep venous thrombosis. Pinto (1970) reported that only 5 of 17 patients with venous thrombosis, shown by the radioactive fibrinogen method, had physical signs. This

Bleeding from other sites Bleeding attributed to Warfarin over dosage occurred as shown in Table 5 Ten patients were involved (4 per cent) of a total of 260 All the patients recovered following a transfusion of between 3 and 6 pints of blood except the patient with cerebral haemorrhage This was a diagnosis based on the development of a hemiplegia 5 days after operation in a 72-year old patient, who survived but with some residual weakness and spasticity in the left arm and leg

Table 5 Bleeding associated with Warfarin overdosage

Haematuria	3
Malaena	2
Extensive bruising	2
Cerebral haemorrhage	1
Retroperitoneal haematoma	1
Bleeding from sacral sore	1

DISCUSSION

The Value of Warfarin as a Prophylaxis for Deep Venous Thrombosis and Pulmonary Embolism

The effectiveness of Warfarin as a prophylactic measure was demonstrated by the fact that only one patient out of 169 (0 6 per cent) maintained with adequate levels of anticoagulant developed a clinically-obvious deep venous thrombosis and no pulmonary emboli were found in this group By contrast inadequate therapy, resulting in prothrombin levels greater than 35 per cent in 79 patients, was associated with 8 cases (10 per cent) of deep venous thrombosis and 7 cases (8 7 per cent) of pulmonary emboli, figures which compare with 10 cases (11 6 per cent) of deep venous thrombosis and 3 (3 4 per cent) pulmonary emboli in the 86 patients in the non treated group (Tables 2 and 3)

Many authors have recorded similar beneficial effects of Warfarin therapy in reducing deep venous thrombosis and pulmonary emboli (Table 6) and this appeared to be so in the present series However, the time between the loading dose and operation is such that in most of the series, including this one, the desired prothrombin level was not reached until 48 to 72 hours post operatively Pinto (1970) who gave Warfarin with the premedication, emphasized the importance of early anticoagulation In view of the fact that 66 per cent of all deep venous thromboses occur within 48 hours of surgery (Negus et al 1969) the

increased in patients who were adequately anticoagulated Careful control of Warfarin therapy is essential since erratic control due to incorrect dosage or the interaction of other drugs can lead to dangerously low prothrombin levels with the risk of wound haematomata and potentially serious bleeding from other sites

SUMMARY

1 A total of 346 patients underwent 112 McKee Farrar, 97 Charnley replacements and 137 intertrochanteric femoral osteotomies All were considered for prophylactic anticoagulation therapy with Warfarin post operatively

2 The patients were in 4 groups depending on the degree of anticoagulation achieved as measured by the prothrombin time

3 Only one deep venous thrombosis and no pulmonary emboli occurred amongst 169 patients in group 1 who received adequate Warfarin therapy

4 There was a comparable incidence of deep venous thrombosis in 79 patients who were inadequately anticoagulated (group 2) and 86 patients who received no anticoagulant for medical reasons (group 4) Pulmonary embolism occurred in 8 7 per cent of patients in group 2 and 3 4 patients in group 4 The differences between groups 1 and 2 and groups 1 and 4 are significant ($P < 0.05$)

5 Wound haematomata occurred with equal frequency (9 per cent) in patients who were adequately anticoagulated (group 1) and the non treated group 4 but were twice as common (21 per cent) in the inadequately-controlled group 2 The differences between groups 1 and 2 and groups 4 and 2 were significant ($P < 0.05$)

6 Well controlled Warfarin therapy commencing on the second post operative day was effective in reducing clinically obvious deep venous thrombosis and pulmonary embolism was completely prevented

ACKNOWLEDGEMENTS

We thank Professor R B Duthie for permission to publish data on his patients who formed the subjects for this review Our thanks are due to Dr A Barr M.Sc (Econ) Ph D Chief Records Officer and Statistician to the Oxford Regional Hospital Board for the statistical evaluation The manuscript was typed by Miss Annabel Filipowska

method is valueless for the diagnosis of ilio femoral occlusions following hip surgery because of the high count around the operation zone This is a serious defect when it is considered that an ilio femoral thrombosis was implicated in 66 per cent of pulmonary emboli (Mavor & Galloway 1969) Venography appears to be a much more satisfactory method of diagnosing occlusions in the important ilio femoral veins (Flanc et al 1968)

Clinical radiological and electrocardiographic diagnosis of pulmonary embolism is reliable in a majority of cases and this appears to be reduced significantly with Warfarin therapy in adequate dosage

Complications of Warfarin Therapy

The commonest complication of Warfarin therapy was wound haematoma There was a 13 per cent incidence of wound haematoma in the 260 patients receiving anticoagulants compared with 10 per cent in 86 patients not treated However there was no difference in the frequency of wound haematoma (Table 4) in patients receiving adequate anticoagulation and those not receiving therapy at all Moreover large haematomata were not necessarily associated with low prothrombin levels and of 7 large haematomas 6 patients had prothrombin times in the region of over 35 per cent and one patient did not receive Warfarin All of the patients recovered from the haematomata and none developed chronic wound sepsis Potentially serious visceral bleeding for example haematuria and malaena (Table 5) were complications of very low prothrombin levels in the 5 to 10 per cent range Although the patients required transfusion all survived the episodes without further complications

The use of anticoagulants for the prevention of deep venous thrombosis and particularly pulmonary embolism remains a subject of controversy With the use of more sophisticated techniques diagnosis and response to therapy will become more precise All agents currently available have disadvantages (Murray & Kakkar 1972) As a result a prospective study employing Warfarin low dose heparin and dextran 70 is under way in this department Meanwhile this review suggests that Warfarin therapy has reduced the incidence of clinical deep venous thrombosis following elective hip surgery Pulmonary embolism has been reduced significantly by Warfarin therapy and it is probable that the value of Warfarin lies in an ability to prevent clot propagation and thereby embolism The incidence of wound haematoma was not

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Aus der Orthopädischen Klinik und Poliklinik der Universität München Germany

SPHERICITY EXAMINATIONS OF ARTHROPLASTIC TOTAL HIP PROSTHESES

M UNGETHÜM, M JÄGER A N WITT & H J HILDEBRANDT

Accepted 29 ix 73

High requirements are put on the materials used, and the design and production of artificial hip joints Important design features are not only tissue compatibility, mechanical stability, wear and corrosion resistance, but also such apparently simple factors as shape and production tolerances Although to a certain extent friction and wear, as well as mechanical stress caused by shock and frictional torque, will inevitably occur, every possible precaution ought to be taken to reduce these detrimental effects to a minimum

One of these harmful influences on the satisfactory functioning of a total hip prosthesis is the deviation of one or both of the articulating surfaces from true roundness Wilson & Scales state that only recently has the importance of geometry and surface finish been apprec[illegible]

1 site of bearing area in the cup,
2 irregular geometry of bearing surfaces of the cup and head, and
3 poor surface finish

These investigators state further that the more perfect the finish of a bearing has to be the higher the cost of the components will become and thus there must be a compromise between that which is theoretically desirable and that which is economically possible and clinically satisfactory

We feel that the highest possible technical standard has to be achieved in order to avoid catastrophic failures caused by seizure under load and a following loosening of the artificial hip replacement There-

The investigations have been supported by the Volkswagen Foundation

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High requirements are put on the materials used, and the design and production of artificial hip joints Important design features are not only tissue compatibility, mechanical stability, wear and corrosion resistance, but also such apparently simple factors as shape and production tolerances Although to a certain extent friction and wear, as well as mechanical stress caused by shock and frictional torque, will inevitably occur every possible precaution ought to be taken to reduce these detrimental effects to a minimum

One of these harmful influences on the satisfactory functioning of a *total hip prosthesis* is the deviation of one or both of the articulating surfaces from true roundness Wilson & Scales state that only recently has the importance of geometry and surface finish been appreciated They believe that in a number of cases of early postoperative loosening the cause was the high initial torque, which was caused by

1 size of bearing area in the cup,
2 irregular geometry of bearing surfaces of the cup and head, and
3 poor surface finish

These investigators state further that the more perfect the finish of a bearing has to be, the higher the cost of the components will become and thus there must be a compromise between that which is theoretically desirable and that which is economically *possible and clinically* satisfactory

We feel that the highest possible technical standard has to be achieved in order to avoid catastrophic failures caused by *seizure* under load and a following loosening of the artificial hip replacement There-

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fore, an experimental examination of the two different types of artificial hip joints mainly being used in our hospital—McKee Farrar and Weber-Huggler—was carried out

It is well known that all technical surfaces show a certain amount of irregularities caused by protrusions, indentations, edges and irregularly slanted planes As will be evidenced further down, our measurements indicate that the assumed spherical surfaces of the prostheses in fact exhibit irregularities such as spikes, small prongs, indentations and nonspherical planes of variable size These deviations from the true sphericity cause high "Hertz" pressures between the articulating surfaces on one hand and high frictional torque on the other

The natural consequence is inadmissably high wear, and the danger of postoperative loosening of acetabular cup or femoral shaft or both

METHODS

Measuring device and examinations

The "Talyrond 100" is a precision instrument for measuring roundness (Figures 1 and 2) The principle of operation is illustrated schematically in Figure 1, which is essentially self explanatory

However it is important to emphasize the following details

1 The radii of the graphs on the recorder charts (see Figures 4 and 5) bear no relationship to the radius of the workpiece
2 Roundness evaluations by means of the recorded graphs are independent of their radii
3 The graph is not to be regarded as a true cross section of the workpiece on a greatly enlarged scale The reason for this is that while the radial magnification is large (e g × 2000) the circumferential magnification is often less than × 1 (i e actually a reduction dependent on the size of some workpieces
4 There is a direct angular relationship between the graph and the workpiece because the chart rotates at the same angular velocity as the turntable both being driven by the same non slip belt Therefore angular positions of irregularities on the workpiece are coincident with the roundness deviations on the chart

Departures from roundness are quoted as the difference between the largest and smallest radii of the sample profile To find the centre of the minimum condition which establishes smallest radial difference one has to position two concentric circles of a polar jig on top of the diagram Two requirements then have to be fullfilled the graph must be entirely enclosed by the circles and the circles must have minimum radial separation

Due to the set magnification the graduation of the polar template corresponds to the true irregularity amplitudes (μm) of the sample The instrument can record up to × 5000 magnification the accuracy of assessment being 0 4 μm In accordance

Figure 1 Schematic diagram showing principle of operation

with the deviation from roundness which was considerably high in a number of measured prostheses only a maximum of × 1000 magnification could be recorded in our examinations As was mentioned above, two types of total hip prosthesis—McKee Farrar and Weber Huggler—have been examined. The McKee Farrar total hip prostheses were produced by three manufacturers (marked "1", "2" and "3") They were supplied from several contractors to obtain highest possible statistical dispersion The Weber Huggler prosthetic implants were made by only one manufacturer (marked "4") 24 endoprostheses of this type supplied from several contractors were tested

The nominal diameters (manufacturer's specification) were divided into two categories

size 1 $1\frac{3}{4}$", $1\frac{9}{16}$", 42 mm diam
size 2 $1\frac{3}{8}$" diam

Roundness was measured in the horizontal planes depicted in Figure 3 (the distance from pole to centre of the head being called h and the coordinate centre of head and cup being identical)

Head plane A at 0 1 h
plane B at 0 75 h
Cup plane C at 0 1 h
plane D at 0 5 h
plane E at 0 75 h

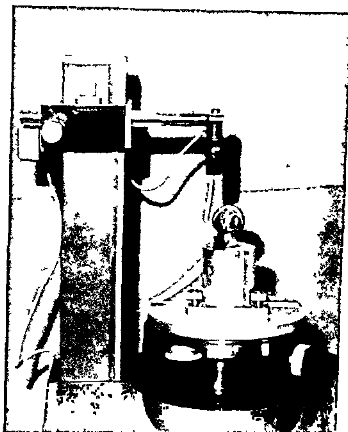


Figure 2 Pick up and turntable

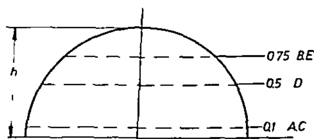


Figure 3 Measuring planes

It must be mentioned that measurements in the frontal and sagittal plane could not be carried out since the 'Talyrond 100' requires one complete revolution for each measurement This however can obviously not be done for the reason of the particular shape of the specimens (incomplete spheres of head and cup)

RESULTS AND CONCLUSIONS

A total of 194 "Talyrond" recordings of an aggregate number of 39 prostheses (head and cup in two and three planes respectively) were

taken giving an overall number of evaluations of more than 2000 taking into account the partition of the polar recording chart into twelve angular sections Examples are shown in Figures 5 and 6 According to the generally accepted definitions of sphericity or non sphericity respectively (e g DIN Norm number 7184) maximum deviations of the arithmetic means of each sample plane can be utilized as well as variance or standard deviation Actually the first quantity is a measure of smaller surface irregularities such as protrusions spikes etc whereas the latter quantities lead to numbers which have a relation to the entire surface deviation from the true sphericity of an ideal body Thus both quantities were derived from the above recordings Figure 4 shows the arithmetic means and the actual maximum deviations of the articulating surfaces in the depicted planes A B C D and E As can be seen clearly there are large differences in the prostheses of the McKee Farrar type among the manufacturers Although the Weber Huggler type prostheses exhibit relatively small roundness deviations this is not at all due to the different kind of material (plastic head metal socket) but rather to the high production standards of the manufacturer "4 the same proving true for the all metal prostheses of manufacturer 3

A similar picture appears for the standard deviations also taken from the above mentioned polar diagrams It does not seem to be very useful to detail all of the 194 standard deviations evaluated However the essential result is that

1 head and cup exhibit a different quality in all prostheses
2 there is no trend with respect to a superiority of head or socket in comparisons between the various manufacturers and
3 the standard deviations calculated for the head (planes A and B) range from 0 1 μm to 40 μm the ones for the cups (planes C D and E) range from 0 1 μm to 21 μm

Although these results show a rather large variety in quality with respect to roundness it can be concluded by these figures that two manufacturers ("3 and 4) are capable of producing prostheses with roundness deviations of the articulating surfaces of less than 3 μm

The success of an implanted total hip prosthesis does of course not only depend on the sphericity of the articulating surfaces In reality it is very difficult to lay down exactly the influence of nonsphericity on wear and friction To minimize this detrimental influence however an optimum accuracy of surface geometry i e roundness and finish

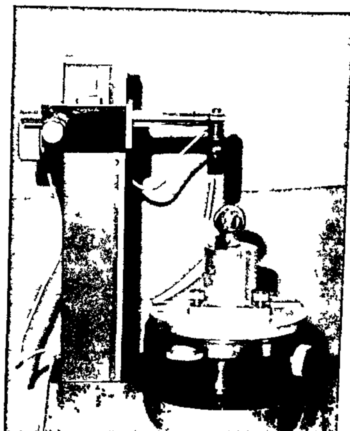


Figure ? Picl up and turntable

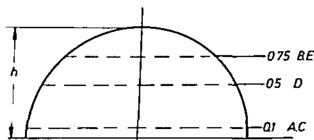
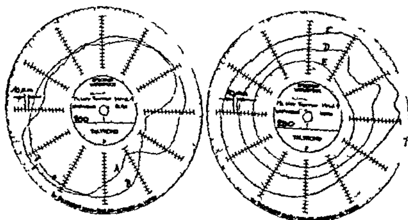


Figure 3 Measuring planes

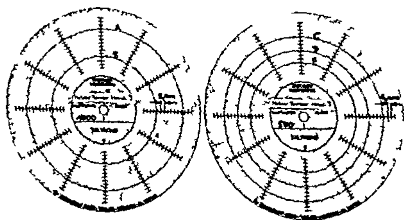
It must be mentioned that measurements in the frontal and sagittal plane c ul l not be carried out since the Talyrond 100 requires one complete revolution for each measurement This however can obviously not be done for the reason f the particular shape of the specimens (incomplete spheres of head and cup)

RESULTS AND CONCLUSIONS

A total of 194 Talyrond" recordings of an aggregate number of 39 prostheses (head and cup in two and three planes respectively) were



F g re 5 Graph of a total h p prosthes s (head left an (cup r ght) of manufacturer 1 × 200 Magn f at on



F gu e 6 Craph of a total h p prosthes s (head left and cup r ght) of manufacturer 3 × 1000 Magn f cat on × 500 Magn f cat on

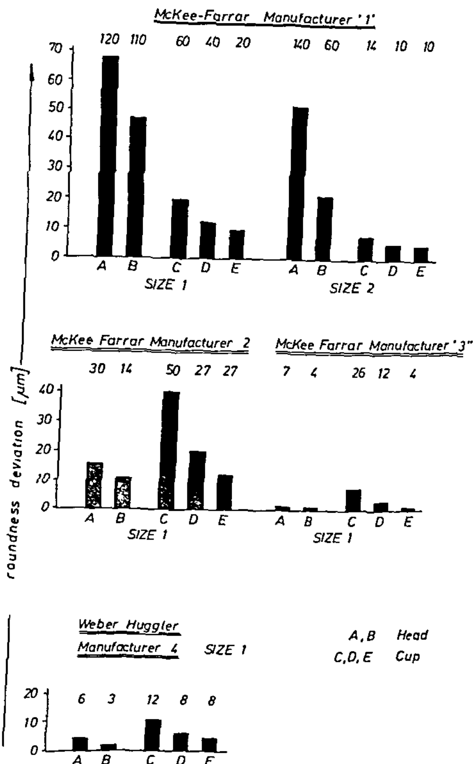


Figure 4 Arithmetic means (column diagrams) of the roundness deviation in five horizontal planes A, B C, D E Numbers on top of the columns show the actual maximum values

Acta orthop scand 45 429-435 1974

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AN *IN VITRO* EXPERIMENT TO DETERMINE THE EFFICIENCY OF FIXATION OF THE McKEE FARRAR ACETABULAR COMPONENT IN RELATION TO TORSIONAL FORCE

S C CHEN, S A LOWE, J T SCALES & R H ANSELL

Accepted 15 x 73

The most important feature contributing to the success of a total hip replacement is the firm and permanent fixation of the components to bone Loosening of the acetabular component always occurs at the polymethyl methacrylate/bone interface Fixation between the acetabular component and the polymethyl methacrylate does not appear to give rise to any problems

Scope

The purpose of the experiment was to determine whether the mechanical strength of the standard McKee preparation was greater than one involving less penetration of the trabecular structure of the os innominatum

Although these experiments have been carried out on dead formalised material it was thought that information might be gained which would lead to the reconsideration of the concept of the fixation of the acetabular component

The efficiency of the fixation in resisting torsion has been examined for two methods of preparation of the acetabulum

1 The standard method advocated by McKee – MK method
2 The twelve Dimple method – TD method

attainable by present day technical standards has to be exacted We hold that a standard deviation of true sphericity of less than or equal to 3 0 μm for both head and cup will prevent high frictional torque caused by initial or eventual jamming under load and will thus give a high degree of reliability of the entire prosthesis

SUMMARY

Friction and wear of total hip prostheses may lead to tissue damaging reactions and loosening of implanted parts An equally serious influ ence on the artificial joint may be exercised by the degree of nonsphericity of the articulating surfaces The present paper investigates the actual roundness of total hip prostheses of the McKee Farrar and Weber Huggler types, of which samples from a variety of manufac turers were inspected The results point out that several commercially available prostheses deviate from sphericity to an extent which cannot be accepted taking into consideration high frictional torque and the danger of loosening of joint components It is suggested that the max imum tolerable standard deviation of sphericity of the articulating surfaces should be 3 0 μm

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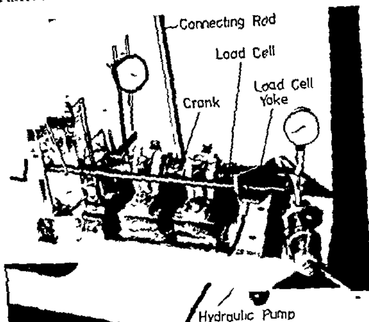


Figure 2

continuous hand pressure was applied until the cement had polymerized The specimens were placed in 10 per cent formal saline solution for 48 hours at room temperature to allow complete polymerization of the acrylic cement They were then mounted in plaster of Paris in the loading fixture and set up in an Instron Universal Testing Machine

The plaster was allowed to set for 5 hours prior to use Before commencement of the test a hole was drilled in the iliac portion of the bone, taking care not to drill into the acrylic plugs, and a 4 mm diameter bone screw was inserted to enable measurement of bone deflections close to the acetabulum to be made A 15 cm lever was mounted on the modified cup at right angles to the cup axle to permit its angular deflection to be measured The fixture containing the specimen was bolted to the base plate of the apparatus, and the cup axle was then connected to the horizontal shaft through which the torque was to be applied via a 5 cm crank After bolting the apparatus to the base plate of the Instron machine a yoke carrying a hydraulic load cell was fitted to enable a constant end load to be applied to the specimen through the horizontal torque shaft (Figure 2) The crank was coupled to the cross head of the Instron by means of a connecting rod The 5 cm crank and connecting rod were arranged at right angles so that a uniform linear movement of the cross head would provide a virtually constant torque on the shaft for the small range of deflections envisaged

Dial indicators were mounted such that movements of the lever mounted on the cup the bone screw and the specimen housing could be measured

Two specimens were used to determine the order of magnitude of the various

PROCEDURE

The McKee Method of Preparation is carried out in the following manner

1 The acetabular cartilage is removed leaving the cortex of the acetabular roof intact
2 All medial and inferior osteophytes in the acetabulum are removed and the original fovea is uncovered The fovea is then roughened
3 The medial border of the intact cortical roof is undermined by about 1 cm
4 1 5 cm diameter holes are drilled 0 5 cm deep into the pubic bone and 2 cm deep into the ischial bone
5 Three drill holes 1 cm in diameter are drilled in the ilium to a depth of 2 cm These holes should not perforate into the pelvis

The Twelve Dimple Method is as follows

1 All cartilage is removed from the acetabulum leaving the cortex of the acetubular roof intact
2 All osteophytes within the acetabulum are removed until the fovea is uncovered
3 Twelve dimples each 0 5 cm in diameter and 0 5 cm in depth are equally spaced in the acetabulum (excluding the fovea)

Casts of acetabulae prepared by the two methods are shown in Figure 1

The os innominata were denuded of soft tissues trimmed and prepared either by the McKee or Twelve Dimple method A dough of Simplex P (non radiopaque) was placed in the acetabulum and care was taken using digital pressure to pack all the holes and dimples A modified acetabular component was inserted and



Figure 1 Acrylic cast of prepared cavities A 12 Dimple B McKee

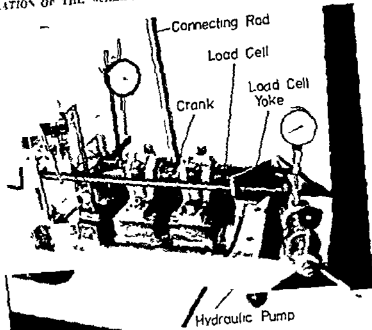


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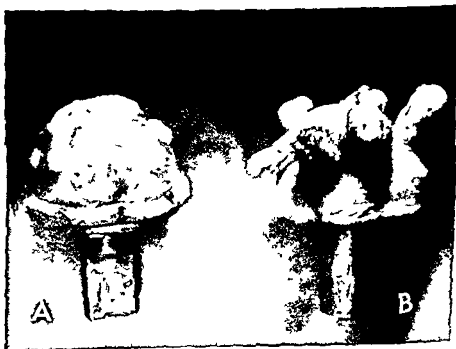


Figure 1 Acrylic cast of prepared cavities A 12 Dimple B McKee

1 Peak torque sustained, and,
2 The slope of the initial straight portions of the graphs, i e the torque strength and stiffness of the two methods of preparation would appear to be the same *in vitro* for these conditions of loading

Table 1

Spec No	Age (years) Sex	R/L	Cause of death	Acetabulum (Diam × Depth) mm	Method of prep	Peak torque (Nm)
1	62 M	R	Coronary	51 × 25	MK	Dummy
2	75 F	R	Carcinoma of Oesophagus	51 × 32	TD	Runs
3	78 M	R	Pneumonia	51 × 32	MK	147
4	85 M	R	Coronary	51 × 25	TD	172
5	79 F	R	Pneumonia	48 × 22	TD	139
6	–	L	Pneumonia	48 × 22	MK	163
7	73 F	R	Coronary	51 × 32	MK	140
8		L	Coronary	51 × 32	TD	249
9	71 F	R	Asphyxia	51 × 22	MK	186
10	81 F	R	Myocardial degen	51 × 25	TD	153
11	86 F	L	Coronary	51 × 22	MK	198
12	68 M	R	Coronary	57 × 32	TD	250
13	78 F	R	Atherosclerosis	51 × 22	MK	95
14	65 F	R	Pulm Embolism	52 × 22	TD	254
15	81 F	R	Myocardial degen	57 × 25	MK	191
16	81 M	R	Coronary	57 × 25	TD	94
17	64 F	R	C V A	57 × 25	MK	170
18	80 F	R	R T A	48 × 22	TD	170
19	60 M	R	Coronary	51 × 25	MK	231
20	84 F	R	Coronary	48 × 25	TD	210

paired acetabulae

The ages and sex of the specimens used for the two methods of preparation were closely matched, and should not have introduced bias into the results obtained The three left acetabulae (two of them paired) did show higher values than the right but the sample was small It was not possible to consider the effect of body weight, as this information was not available

For a given torque the resisting torque at the bone/acrylic interface will be dependent upon the diameter of the acetabulum, and therefore, the results were compared grouping them by their acetabular diameter There was possibly a tendency for the 12 hole preparation to be less stiff though many more results would be necessary to clarify this

test parameters Hysterises loading, i e successive incremental loading with a return to zero between each load application was adopted since it was hoped to be able to use a pre-determined amount of permanent deformation as an indication of failure, to compliment the work of Parsons et al (1970) On the basis of the results obtained from these two specimens the following conditions were used

Torque – The torque was increased in incremental steps of 22 5 Nm (200 lbf") allowing the load to return to zero between each increment

End Load – a continuous end load of 1 1 kN (250 lbf") was applied through out the test

Rate of loading – a crosshead speed of 04 mm/s (1 in/min) was used, correspond ing to a rate of angular deflection of the torque shaft of 5 75°/min

Failure was defined as continuous rotation of the torque shaft without increase in load, with or without a visible crack between acrylic and bone

A number of specimens were carefully dissected out from the bone after test to see if any visible cracking of the acrylic had occurred

Radiographs were made of the first ten preparations before and after applying loads to failure Although high resolution industrial C film was used no detail of bony failure could be seen and this procedure was discontinued

MATERIAL

Human hip bones from subjects about 60 years of age, who had been leading an active life within 48 hours of death (see Table 1 for cause of death) Following death, the bodies were chilled (3 3° C) prior to postmortem examination After removal at postmortem examination the bones were preserved in 10 per cent formal saline solution from 3 days to 5 days when they were used for the experiment

Four standard McKee-Farrar acetabular components of 50 mm outside diameter were modified to include a welded short axle to enable a torsional stress to be applied

RESULTS

No visible cracking of the acrylic could be detected

The peak torques achieved are tabulated in Table I

From the dial indicator reading it was possible to determine the deflections of the cup relative to the base and to the bone, measured at the position of the bone screw

For each preparation, graphs were prepared, plotting displacement of the cup relative to the base against torque Graph of the mean values of the results are shown in Figure 3

Analysis of the results showed no significant difference between the two methods of preparation with reference to

softer and weaker foundation for the acetabular cup, especially in rheumatoid patients

CONCLUSIONS

The results obtained suggest that a re evaluation of the efficiency of the standard method of preparation of the acetabulum for a McKee replacement should be undertaken It is possible that, *in vivo*, the drilling of large, deep holes into the trabecular structure of the bone and the subsequent reorganisation of the tissue after polymerisation of the acrylic will affect its mechanical properties In addition, the blood supply traversing the cancellous bone may be markedly interfered with Experiments carried out by Thomas (1965) suggest that this area is worthy of further study, since it is suggested that the blood supply to the acetabular roof is from an arcuate branch of the superior gluteal artery which sends smaller branches into the bone from the acetabular rim Damage done to this blood supply during the creation of the large holes and the heat of polymerisation of the acrylic could lead to areas of necrosis This would reduce the integrity and hence mechanical strength of the trabecular structure leading to failure under torque loads

Since completion of our experiment, Andersson et al (1972) working independently arrived at similar conclusions

ACKNOWLEDGEMENTS

The authors wish to thank for their assistance Mr R Childs and Mr J D Wood Department of Biomedical Engineering and the Medical Photography Department of the Royal National Orthopaedic Hospital and the George Stephenson College Watford for the manufacture of the loading jig

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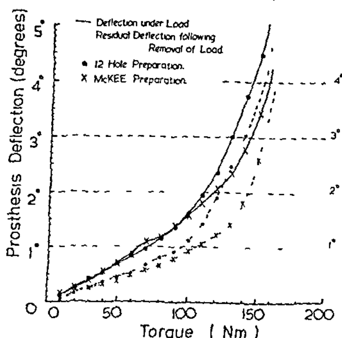


Figure 3 Graph of cup deflection against torque

DISCUSSION

There would appear to be no significant difference in the mechanical strength of the fixation to resist torque between the two methods of preparation under laboratory conditions

The possibility must also be considered that under fatigue loading conditions a difference might appear The large acrylic plugs or the more extensively disrupted trabecular structure of the McKee preparation might be expected to suffer fatigue failure more readily than the 12 hole preparation Some fatigue work was attempted but results were inconclusive due to inability of the machine to withstand prolonged cyclic operation

Examination of the metal and acrylic materials showed no failure The specimens were prepared by one person using precision drills and measurements

Examination of the bone specimens used in the experiment showed normal trabecular structure, absence of cysts, osteophytes or any abnormalities The articular cartilage appeared normal, and the capsule and ligamentous structures were also normal In orthopaedic practice however, the bone is usually poor, with cysts, osteophytes, and has a

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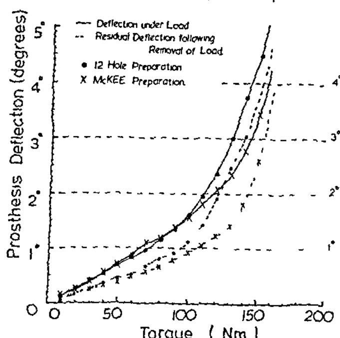


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s weighted by the fact that a part of it comprises patients with complaints *in* the knee joints

Insall & Salvati (1971) approached a clarification of the problem, when they examined a series of 44 knees with isolated meniscus injuries (operatively verified), and measured the position of the patella in relation to the BL at 30 degrees of knee flection. This investigation showed that the patella was located considerably higher than suggested by Blumensaat. We are of the opinion that this material is not necessarily representative as a normal material concerning the position of the patella as the possibility exists that a relatively high location of the patella in these patients may have been predisposing for a meniscus lesion in the joint.

For that reason we have examined a series of persons who have never had any lesions, medical diseases or complaints in their knee joints.

Table 1. The age and sex distribution in the material

Age	Women	Men	Total
20–30	21	21	42
31–52	3	5	8
20–52	24	26	50

MATERIAL AND METHOD

The material comprises the lateral radiographs of 100 knees from 50 persons, 26 men and 24 women, who have never had any lesions, joint diseases or complaints in the knee joints, and whose knees have been found sound on clinical examination. On the basis of this examination we excluded subjects who showed atrophy of the quadriceps muscle, effusion in the knee joint, thickening of the capsule, reduction of movements in the joint, lateral looseness, rotary looseness and drawer sign, tenderness of the joint line as well as marked laxity of the posterior capsule. Thus we excluded persons with a possibility of extension in the knee that exceeds the 195 degree position (measured on the fibular side of the lower extremity from the point of the malleolus to the epicondylus femoris and the point of the greater trochanter). Moreover persons with a valgus deformity of the knee joints which exceeds 10 degrees were excluded, as Thestrup Andersen (1935) in a material of persons with sound knees found a variation of the angle between the femur and the tibia in the frontal plane between 0 and 10 degrees. All the radiographs are without pathological findings. The length of the lower extremity has been measured from the point of the greater trochanter to the point of the fibular malleolus.

The age and sex distribution appears in Table 1. The participating persons are students, physicians, nurses and hospital porters. Nearly all of them participate in some kind of sport, but only one in competitive athletics.

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THE VERTICAL LOCATION OF THE PATELLA

Fundamental Views on the Concept Patella Alta, using a Normal Sample

KLAUS JACOBSEN & KJELL BERTHEUSSEN

Accepted 27 viii 73

Patella alta, p a , high riding patella, is a purely morphological concept To what extent p a has an influence on disorders or complaints of the knee joint is still under discussion and not yet clarified

Even as a morphological concept, p a is not exactly defined The establishment of a diagnosis of high location of the patella is only possible with certainty if one knows the limits of the normal variation As far as we know, an investigation of the vertical position of the patella in persons without any knee joint complaints has not hitherto been carried out

Blumensaat (1938) has given the most commonly used definition At a knee flection of 30 degrees (the 150 degree position) the apex of the normally located patella will touch the extension of a condensed line, which on the lateral radiograph of the knee is seen in the condylar *massif* of the femur and represents the "roof" in the intercondylar fossa, the line of Blumensaat, I Bl A patella with any higher position will be named a p a However, Blumensaat's suggestion is only a rough estimate, no exact measurements are given as reason for this definition "Bei einem Beugungswinkel von etwa 150 Grad nun pflegt, wie wir uns stets uberzeugen konnten, die gedachte Verlangerung dieser interkondylaren Begrenzungslinie nach vorne mit dem unteren Kniescheibepol zusammenzufallen "

On the basis of 200 lateral radiographs of knee joints, Boon-Itt (1930) proposed an index for the patellar position by means of a geometric system For clinical use, this method is too cumbersome, without affording a guarantee of exact values Moreover, the material

Aided by a grant from the Danish Medical Research Council

Table 2 Distribution of the measured values of the distance a from the apex patellae to the line of Blumensaat

a mm	Right	Left	Total	Men	Women
0–5	0	0	0	0	0
6–10	5	8	13	3	10
11–15	18	18	36	16	20
16–20	8	14	22	14	8
21–25	14	6	20	10	10
26–30	4	4	8	8	0
31–35	1	0	1	1	0

RESULTS

The distribution of the distance, a, in the material is given in Table 2 The mean of a is 17 mm for the total material The median is 16 mm The 2½ per cent percentile is 7 mm and the 97½ per cent percentile is 29 mm From this it follows that 95 per cent of the material has a distance, a, in the interval from 7 to 29 mm

As the question concerned is the high location of the patella, p a, especially the upper limit, the 97½ per cent percentile is of interest A reasonable upper limit for the normal location of patella will thus

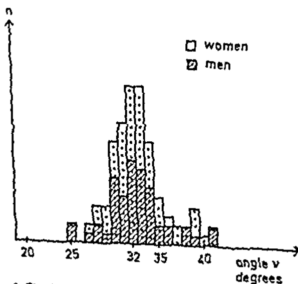


Figure 2 The distribution in the material of the values of the angle v

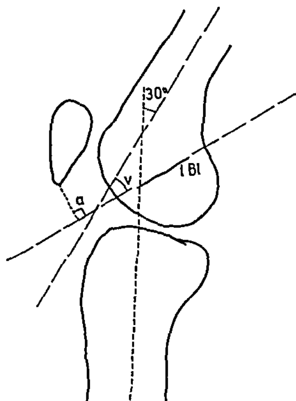


Figure 1 Diagram showing the distance, a, from the apex of the patella perpendicular to the extension of the line of Blumensaat, l Bl, and the angle, v between the axis of the shaft of the femur and the l Bl Knee flection 30 degrees

The lateral radiographs have been obtained with the knees in exactly 30 degrees of flection (the 150 degree position) by means of a special fixation The angle between the axes of the femoral and tibial shafts was checked on the radiograph before the procedure was ended The graphs have been made with a raster in the plate holder to obtain parallel rays and the magnification varies between 1 06 and 1 12

The distance, a, from the apex of the patella is measured at right angles to the extension of the l Bl (Figure 1) by means of a Vernier scale on a transparent template with perpendicular vertical and horizontal lines placed over the radiograph in a horizontally placed illuminated viewing box The measurements are carried out to an accuracy of 1 mm

The angle, v, between the axis of the femoral shaft and the l Bl (Figure 1) has been measured as proposed by Brattstrom (1970)

As radiographs of the knee in the exact 150 degree position are difficult to obtain without a special fixation and careful technique, Insall & Salvati (1971) have proposed the following index LT/LP The greatest diagonal length of the patella is LP and the length of the patellar tendon LT The length of the patellar tendon is measured from the apex patellae to the small notch just proximal to the tibial tuberosity on the lateral radiograph

This index has been calculated as well

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16–20	8	14	22	14	8
21–25	14	6	20	10	10
26–30	4	4	8	8	0
31–35	1	0	1	1	0

RESULTS

The distribution of the distance, a, in the material is given in Table 2 The mean of a is 17 mm for the total material The median is 16 mm The 2½ per cent percentile is 7 mm and the 97½ per cent percentile is 29 mm From this it follows that 95 per cent of the material has a distance, a, in the interval from 7 to 29 mm

As the question concerned is the high location of the patella, p a, especially the upper limit, the 97½ per cent percentile is of interest A reasonable upper limit for the normal location of patella will thus

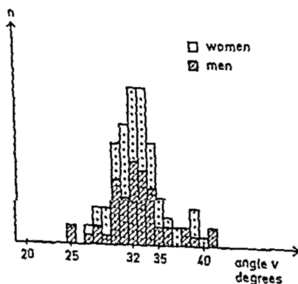


Figure 2 The distribution in the material of the values of the angle v

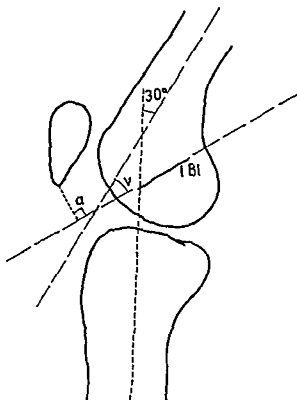


Figure 1 Diagram showing the distance, a, from the apex of the patella perpendicular to the extension of the line of Blumensaat, l Bl, and the angle v, between the axis of the shaft of the femur and the l Bl Knee flection 30 degrees

The lateral radiographs have been obtained with the knees in exactly 30 degrees of flection (the 150 degree position) by means of a special fixation The angle between the axes of the femoral and tibial shafts was checked on the radiograph before the procedure was ended The graphs have been made with a raster in the plate holder to obtain parallel rays and the magnification varies between 1 06 and 1 12

The distance, a, from the apex of the patella is measured at right angles to the extension of the l Bl (Figure 1) by means of a Vernier scale on a transparent template with perpendicular vertical and horizontal lines placed over the radiograph in a horizontally placed illuminated viewing box The measurements are carried out to an accuracy of 1 mm

The angle, v, between the axis of the femoral shaft and the l Bl (Figure 1) has been measured as proposed by Brattstrom (1970)

As radiographs of the knee in the exact 150 degree position are difficult to obtain without a special fixation and careful technique, Insall & Salvati (1971) have proposed the following index l T/LP The greatest diagonal length of the patella is LP and the length of the patellar tendon LT The length of the patellar tendon is measured from the apex patellae to the small notch just proximal to the tibial tuberosity on the lateral radiograph

This index has been calculated as well

Table 2 Distribution of the measured values of the distance a from the apex patellae to the line of Blumensaal

a mm	Right	Left	Total	Men	Women
0–5	0	0	0	0	0
6–10	5	8	13	3	10
11 15	18	18	36	16	20
16–20	8	14	22	14	8
21 25	14	6	20	10	10
26–30	4	4	8	8	0
31–35	1	0	1	1	0

RESULTS

The distribution of the distance, a, in the material is given in Table 2 The mean of a is 17 mm for the total material The median is 16 mm The 2½ per cent percentile is 7 mm and the 97½ per cent percentile is 29 mm From this it follows that 95 per cent of the material has a *distance*, a, in the interval from 7 to 29 mm

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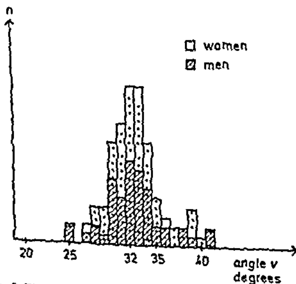
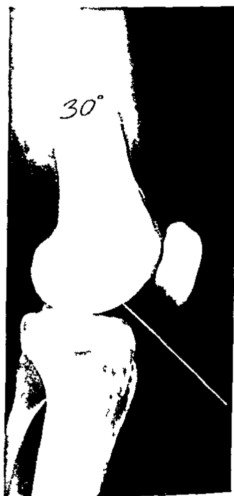


Figure 2 *The distribution in the material of the values of the angle v*

Figure 3 a Lateral radiograph of the right knee of a normal person 30 degrees of knee flection Note that the extension of the line of Blumensaat is well below the apex patellae



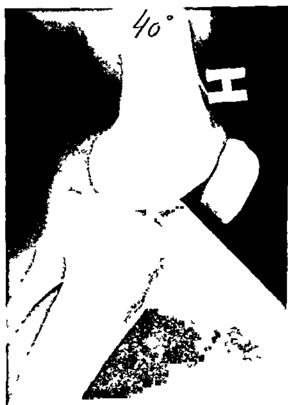


Figure 3 b Lateral radiograph of the same knee as in Figure 3 a 40 degrees of knee flection Note that the extension of the line of Blumensaat is very close to the apex patellae

be 30 mm In our material (Table 2), only one knee has a distance a, which exceeds this limit

The average value of a, the mean, is 18 9 mm for men and 15 5 mm for women The difference is statistically significant on a one per cent level ($P = 0\ 01$)

The average length of the lower extremity, measured from the point of the greater trochanter to the point of the fibular malleolus, is 86

cm for men, and 79 cm for women If the value 79/86 is used as a corrective factor, the mean for men will be reduced to 17 4 mm If all the male values of a are multiplied with this corrective factor there will no longer be a statistically significant difference between female a-values and corrected male a-values This means that the greater male distance a is presumably due to the greater average physical proportions of the male

One might think from this, that the variation of a inside the male group was due to the differences in physical proportions However, after correction of all male a values with a factor f' = 86/ measured length of the extremity concerned, which means that all male extremities have been corrected to the average length, there is an unaltered dispersion in the male material (95 per cent between 8 and 32 mm) The highest values, which exceed these limits, are due to the above mentioned person with an uncorrected a value exceeding 30 mm The length of the lower extremities of this person is smaller than the average

In women, as well as in men, the distance a is biggest on the right side, averaging in men 19 8 mm on the right and 18 0 mm on the left side, and in women 16 3 mm on the right and 14 6 mm on the left side, but the differences are not significant on a 5 per cent level

The angle, v, between the axis of the femoral shaft and the L Bl (Figure 1), varies in the material, as shown in Figure 2, inside a narrow interval around the mean value 32 6 degrees The median is 32 degrees the 2½ per cent percentile 26 degrees and the 97½ per cent percentile 40 degrees This means that 95 per cent of the values are between 26 degrees and 40 degrees

The individual differences between right and left angle v are very small averaging 1 6 degrees the range is from 0 to 5 degrees

We have furthermore examined a few persons with the knee both in the 150 degree and in the 140 degree or 135 degree position and observed that the distance, a, during the last 10 to 15 degrees of flection is diminished drastically, see Figures 3 a and 3 b

In our sample of normal subjects the index of Insall & Salvati, LT/LP varies as shown in Table 3 The median is 1 0, the 2½ per cent percentile 0 9 and the 97½ per cent percentile 1 3 The upper limit for normal knees is thus 1 3, and knees with an index greater than this can be designated p a , as a high location of the patella will give a large index In a later publication Insall et al (1972) used the reciprocal index, which does not seem logical to us

Table 3. Distribution of the index of Insall & Salvati for the location of the patella Total material.

Index: LT/LP	0.7	0 8	0 9	1 0	1.1	1 2	1.3
Knees	0	1	19	39	20	18	3

DISCUSSION

We have verified above that the normal patella is located considerably higher than suggested by Blumensaat. We therefore cannot accept his definition. If it is used, p.a. must be characterized as physiological. If certain symptoms from the knee joint are to be explained by a high location of the patella, one must use a more exact criterion on the basis of the limits of the normal location of the patella. In accordance with our investigations, we propose that the term p.a only be used when the patella is located more than 30 mm over the extension of the l. Bl. measured perpendicularly from this to the apex patellae, when the knee flection is exactly 30 degrees (the knee being in the 150 degree position).

An exact measurement of the angle of knee flection is of decisive importance to the value of the distance a. As this value at 30 degrees of knee flection averages 17 mm and may be 30 mm, it is considerably smaller at about 45 degrees of knee flection.

This small difference in the angle of knee flection, 15 degrees, is easy overlooked on the radiograph if a measurement is not carried out.

As a schematic outline the tibia and the apex patellae can be regarded as fixed during the knee flection, while the femoral condyles with the l Bl. are the moving parts The l. Bl., then, turns like a watch hand in the direction of the apex patellae The hand moves a greater distance from 30 degrees to 45 degrees than it does from 15 degrees to 30 degrees of knee flection, as the curve of the femoral condyles improves (the radius diminishes) during the knee flection An exact analysis of this movement is, however, much more complicated, as the apex patellae actually moves posteriorly along an arc of a circle, the centre being the insertion of the patellar tendon on the tuberosity of the tibia Moreover, besides the watch hand movement, the l Bl has a complicated movement in which the posterior point follows a curved line

The results in our sample of normal subjects prove to be in accordance with the results of Insall & Salvati, and so we can now reject the doubt which we put forward above concerning their premises (that

the material of patients with meniscus lesion could represent a normal sample)

A difference in the distance, a, in men and women appears to be a result of the average larger physical proportions of the human male

There is no statistically significant difference in the location of the patella between the right and the left knee

Brattstrom suggests that the angle, v, between the axis of the femoral shaft and the l Bl, is normally 45 degrees, and states in his material a great dispersion of the values We cannot confirm these findings, as we in our material have demonstrated a considerably smaller angle v The median in the material is 32 degrees, and there is only a small dispersion, as 95 per cent of the values lie between 26 degrees and 40 degrees The difference between the angle v on the right and the left knee in the same person is negligible

We therefore cannot agree with Brattström's proposal to designate a patella with a distance, a, of, for example, 20 mm and an angle, v, of 30 degrees a "false patella alta" We must assert that it is a case of normal location of the patella We also cannot agree with the proposal of the same author to correct an angle, v, of about 30 degrees to the value 45 degrees

These considerations appear to us to make the definition of p a more clear as a morphological-anatomical concept Whether p a has any sense as a "unity of disease" cannot be stated from this investigation but selection of a possible patient material must follow other criteria than those used up till now

From a practical point of view it is difficult to obtain routine radiographs with a knee flection of exactly 30 degrees, and so we can agree with the proposal of Insall & Salvati for another measure for the location of the patella, than the relation to the l Bl Also, from a theoretical point of view, it seems logical to use a measure in which the length of the patellar tendon is related to the length of the patella, as it is exactly the mutual magnitude of these structures that determines the location of the patella The value of this index, LT/LP, in our material is in good agreement with the results of Insall & Salvati The average value in our material, as well as in the material of Insall & Salvati (1971) is 1 0 The upper limit of the normal area is 1 3 according to our material, and so persons with a larger index may be characterized by the term p a We propose that this index be used in the future

Table 3. Distribution of the index of Insall & Salvati for the location of the patella. Total material

Index LT/LP	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Knees	0	1	19	39	20	18	3

DISCUSSION

We have verified above that the normal patella is located considerably higher than suggested by Blumensaat. We therefore cannot accept his definition. If it is used, p.a. must be characterized as physiological. If certain symptoms from the knee joint are to be explained by a high location of the patella, one must use a more exact criterion on the basis of the limits of the normal location of the patella. In accordance with our investigations, we propose that the term p.a. only be used when the patella is located more than 30 mm over the extension of the l. Bl. measured perpendicularly from this to the apex patellae, when the knee flection is exactly 30 degrees (the knee being in the 150 degree position).

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SUMMARY

Much confusion has been brought into the discussion of the concept patella alta by Blumensaat's inexact *definition* We *have therefore* investigated the vertical location of the patella in 100 normal knees The subjects were selected by means of a thorough clinical examination *Their medical histories* showed no injuries or medical or surgical joint diseases and their radiographs showed no lesions in the knee joint

The mean distance from the apex patellae measured at right angles to the extension of the line of Blumensaat on the lateral radiograph with the knee in a position of exactly 30 degrees of flection (the 150 degree position), is 17 mm The 97½ per cent percentile is 29 mm Thus, we are of the opinion that a distance of 30 mm is a reasonable upper limit for the normal vertical position of the patella The term patella alta should be reserved for the cases with an even larger distance

There is *no statistically significant difference between right* and left knees and, after correction for the average greater length of the male lower extremity, there is no significant difference between the distance in men and women The angle, x, between *the axis of the femoral shaft* and the line of Blumensaat, is found to be 32 6 degrees in average, with a small dispersion Thus, we cannot agree with another author who suggests the angle x to be 45 degrees, and who proposes a *correction* of a 30 degree angle to 45 degrees

As radiographs of the knee joint with an angle of exactly 150 degrees between the femur and the tibia are difficult to obtain in practical daily work, and as it seems logical to use a measure in which the length of the patellar tendon, LT, is correlated to the length of the patella, LP, we propose to use the index of Insall & Salvati LT/LP In accordance with our material the upper limit for LT/LP should be 1 3 in normal knees

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CONGENITAL ABSENCE OF THE FIBULA

KNUD JANSEN & KJELD SKOU ANDERSEN

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Examination and management over many years of children with absence of the fibula has made it obvious that the deficiency is not confined to the directly visible anatomical defect, but that it has an affect on the whole leg. The purpose of this report is to submit some observations on children with congenital absence of the fibula who have undergone various forms of treatment.

MATERIAL AND METHODS

In the period 1924 to 1968, 29 cases of congenital absence of the fibula have been treated at the Orthopaedic Hospital in Copenhagen. In 21 cases the absence was unilateral and was not associated with other severe congenital deformities. According to the classification of Coventry & Johnson (1952) all these 21 cases could be classified in groups I and II (partial unilateral absence of the fibula and complete absence of the fibula with minimal or no associated abnormalities).

The distribution according to side and sex is shown in Table 1. In all cases there was shortening of the affected leg, in 18 cases combined with angulation of the lower leg and in 12 cases with a dimple of the skin. A pronounced valgus deformity in the ankle joint was found in 20 cases, in 7 cases there was a valgus deformity in the knee joint probably due to unequal growth of the epiphyses near the knee joint (Figure 1), and in 2 cases the angle of the femoral neck was increased in comparison with the opposite side (Figure 2).

In 9 cases there was a normal number of metatarsal rays in the foot on the affected side, and apart from a slight hypoplasia and a delayed development of the bones, the foot appeared radiologically normal. In the remaining 12 cases there was a decreased number of metatarsal rays with growth abnormalities of the bones in the foot. In 4 cases a bony coalition between the calcaneum and the talus was found.

Twelve patients were first seen not later than one month after birth and only 3 patients were over one year of age when first examined. All patients were seen regularly until skeletal maturity was reached or until 1972. From 1952 the normal clinical and radiological examination was supplemented with an orthoradiological examination in order to study the growth rate of the legs. The results of these examinations are shown in Table 2. In the femur the average percentage inhibition

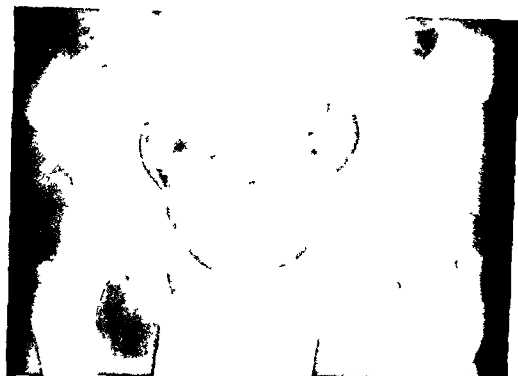


Figure 2. Increased valgus angulation of the femoral neck in a leg with congenital absence of the fibula in comparison with the opposite side

results of the epiphysiodeses be evaluated. In one case the estimated correction was obtained whereas only 50 to 75 per cent of the estimated correction was obtained in the remaining cases.

The deformities of the foot were treated with manipulations and corrective casts during the first years of life. In 6 cases resection of the fibular fibrous band was performed. It has not been possible to make on evaluation of this treatment however.

Out of a total of 8 patients with only 2 or 3 metatarsal rays in the foot on the

Table 2. Results of clinical, radiological and orthoradiological examinations used to study the growth rate of the legs

		Number of metatarsal rays in foot of affected leg			
		2	3	4	5
The average leg length discrepancy (mm)	Femur	7	20	15	14
as measured in the first year of life	Tibia	60	20	40	17
The average growth retardation (mm)	Femur	3	3½	1	2
per year	Tibia	9	6	4	2½
The percentage inhibition of growth	Femur	5	11	6	10
(average value)	Tibia	35	30	5	10

Table 1 The distribution of the 21 cases of congenital absence of the fibula according to sex and side.

	Side		Sex		Total
	male	female	right	left	
Foot with 2 metatarsal rays	1	2	2	1	3
Foot with 3 metatarsal rays	5	–	4	1	5
Foot with 4 metatarsal rays	4	–	2	2	4
Foot with 5 metatarsal rays	4	5	3	6	9
Total	14	7	11	10	21

of growth was found to be 9 and in the tibia 22 The average growth deficiency of the femur was 2 mm per year (0–6 mm) and of the tibia 4 mm (1–9 mm) In 2 patients a femoral length discrepancy of 1½ and 2 cm was found in the first year of life, but later examinations revealed no growth retardation of the femur and the growth rate of the femur on the affected side was found equal to that of the femur on the opposite side

In order to control the leg length discrepancy growth stimulating operations and epiphysiodeses were performed No cases of operative leg lengthening have been done The stimulating operations were not effective and in only 3 cases could the



Figures 1 a b Increased growth of the medial part of the distal femoral epiphysis in a leg with congenital absence of the fibula in comparison with the opposite leg



Figure 2 Increased valgus angulation of the femoral neck in a leg u t absence of the fibula in comparison with the opposite side

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per year	Tibia	9	6	4	$2^1{}_2$
The percentage inhibition of growth	Femur	5	11	6	10
(average value)	Tibia	35	30	5	10

Two factors are of special importance when treatment is discussed the abnormalities of the foot on the affected side and the leg length discrepancy In addition, however, soft tissue abnormalities, associated congenital deformities and age have to be considered In order to provide and preserve a functional foot, numerous operative treatments have been published (Harmon & Fahey 1937, Serafin 1967) and in order to minimize the leg length discrepancy, growth stimulation, growth inhibition and bone lengthening procedures have been advocated (Pappas et al 1972)

The aim of the treatment should be to provide the patient with the best possible extremity In order to obtain this aim, not only bracing, but also multiple surgical procedures may often be necessary This does not only include osteotomies of the tibia, tendon lenthening, and soft tissue release but also epiphysiodeses on the opposite leg in order to control the leg length discrepancy

Investigations of the growth rate of the long bones in cases of congenital absence of the fibula seem to be only seldom reported in the literature Kruger & Talbott (1961) found that the leg length discrepancy was more pronounced in cases with 5 metatarsal rays in the foot than in cases with only 3 rays This is not in agreement with our findings which showed an increasing percentage inhibition of growth in the tibia in proportion to the severity of the foot deformity On the other hand no relationship could be found between the percentage inhibition of growth in the femur on the affected side and the number of metatarsal rays in the foot In only 2 cases did the percentage inhibition of growth in the femur exceed 10 In contrast to the report of Pappas et al (1972) the leg length discrepancy as measured at the first examination could not be related to the percentage inhibition of growth of the tibia nor to the ultimate leg length discrepancy

The treatment has then been associated with multiple surgical procedures and many hospitalizations though the end result has often left a great deal to be desired In view of these often faulty therapeutic trials and their psychosocial and economical consequences, more authors (Aitken 1959 Kruger & Talbott 1961, Wood et al 1965) have been advocating early amputation The indications have been gross abnormalities of the foot and an expected severe ultimate leg length discrepancy

Amputation however, might not always be a single definitive operative procedure In our material more than half of the amputated patients had a secondary operative intervention later Even if the

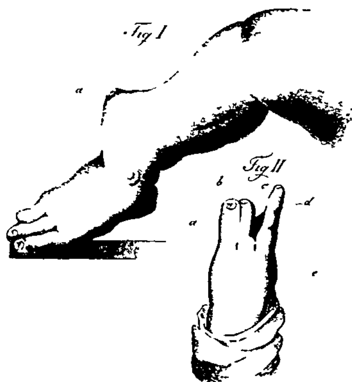


Figure 3 Congenital absence of the fibula From Sachse (1800)

the decreased growth rate of the long bones in the affected leg are of much greater importance Thus, for example, the proximal femoral focal deficiency, which often is associated with absence of the fibula is classified by most authors as an independent entity, and only by a few authors (Coventry & Johnson 1952) still looked upon as a case of congenital absence of the fibula

Congenital absence of the fibula has been classified by Coventry & Johnson (1952) into 3 groups, which were later modified by Kruger & Talbott (1961) In our material this classification was only of limited use Thus 4 patients who could all be classified in Coventry & Johnson's group I, all exhibited retardation of the growth of the femur with a percentage inhibition of growth between 5 and 10

In our opinion the problems of treatment in cases of bilateral absence of the fibula and in cases associated with other congenital deformities, differ essentially from the problems in cases of unilateral absence of the fibula Because of this essential difference, cases of bilateral absence or cases associated with other congenital deformities have not been included in this report

Two factors are of special importance when treatment is discussed the abnormalities of the foot on the affected side and the leg length discrepancy In addition, however, soft tissue abnormalities, associated congenital deformities and age have to be considered In order to provide and preserve a functional foot, numerous operative treatments have been published (Harmon & Fahey 1937, Serafin 1967) and in order to minimize the leg length discrepancy, growth stimulation, growth inhibition and bone lengthening procedures have been advocated (Pappas et al 1972)

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Amputation, however, might not always be a single definitive operative procedure In our material more than half of the amputated patients had a secondary operative intervention later Even if the

problems of overgrowth are put aside, there are still 4 amputated patients with secondary operations The indication was the progressing valgus deformity in the knee or the equinus position of the foot in patients with amputations through the mid-foot The rising number of operations on these patients, however, even the amputated ones, may to a certain degree be taken as an indication of a growing interest in the fate of these patients

CONCLUSIONS

Planning of the treatment must be based upon the defects of the foot and the ankle joint, the ultimate leg length discrepancy and the abnormalities of the soft tissue If it is decided that a functional foot and ankle joint might be able to be preserved (as estimated from a thorough examination of not only osseous but also muscular and ligamentous conditions) an evaluation of the growth pattern and the percentage retardation of the femur and the tibia should be performed We think that the early leg length discrepancy is of only limited value in estimating the ultimate discrepancy, and that a careful investigation of the growth rate of the long bones in the affected leg might be of advantage If it is predicted that the ultimate leg length discrepancy will be under 10 cm, early constructive surgical procedures are indicated

If a functional foot or ankle joint cannot be preserved, if there is a lack of epiphyseal development, or if the ultimate leg length discrepancy is predicted to exceed 10–15 cm an early amputation might be indicated In these instances the Syme's amputation probably is the best surgical procedure

In congenital absence of the fibula virtually no two cases are alike Even if some general remarks regarding treatment have been made, we want to stress that the treatment here more than anywhere else must be individualized to a high degree

SUMMARY

On the basis of 21 cases with unilateral congenital absence of the fibula, some observations on the growth rate of the affected leg and the problems of treatment are submitted

ACKNOWLEDGEMENT

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problems of overgrowth are put aside there are still 4 amputated patients with secondary operations. The indication was the progressing valgus deformity in the knee or the equinus position of the foot in patients with amputations through the mid foot. The rising number of operations on these patients, however, even the amputated ones, may to a certain degree be taken as an indication of a growing interest in the fate of these patients.

CONCLUSIONS

Planning of the treatment must be based upon the defects of the foot and the ankle joint, the ultimate leg length discrepancy and the abnormalities of the soft tissue. If it is decided that a functional foot and ankle joint might be able to be preserved (as estimated from a thorough examination of not only osseous but also muscular and ligamentous conditions) *an evaluation of the growth pattern and the percentage* retardation of the femur and the tibia should be performed. We think that the early leg length discrepancy is of only limited value in estimating the ultimate discrepancy, and that a careful investigation of the growth rate of the long bones in the affected leg might be of advantage. If it is predicted that the ultimate leg length discrepancy will be under *10* cm, early constructive surgical *procedures are indicated.*

If a functional foot or ankle joint cannot be preserved, if there is a lack of epiphyseal development, or if the ultimate leg length discrepancy is predicted to exceed 10–15 cm an early amputation might be indicated. In these instances the Syme's amputation probably is the best *surgical procedure.*

In congenital absence of the fibula virtually no two cases are alike. Even if some general remarks regarding treatment have been made we want to stress that the treatment here more than *anywhere else* must be individualized to a high degree.

SUMMARY

On the *basis of 21 cases* with *unilateral* congenital absence of the fibula some observations on the growth rate of the affected leg and the problems of treatment are submitted.

ACKNOWLEDGEMENT

For permission to use reports and X-rays thanks are due to I. Hj. Larsen, M.D. and J. Saugmann-Jensen, M.D., Orthopaedic Hospital, Copenhagen.

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Figure 3. Rather large bone fragment in the right ankle (orienteerer aged 38)

Anatomy

The posterior talotibial ligament runs from the dorsal and distal part of the medial malleolus and inserts in the medial tubercle of the talus (Figure 1). This ligament stabilizes the joint when the talus occupies a position of dorsal extension and pronation in the ankle mortise. With a heavy breaking force in the direction of dorsal extension and pronation the strength of the ligament is *exceeded and a rupture* occurs which can be combined with the avulsion of a bone fragment from the talus (Figure 2).

MATERIAL

The patients were all young active sportsmen aged 38, 25, 22 and 20. The oldest was an orienteerer, the others were football players. In practising their sport all of them had received a heavy distortion trauma to the right ankle followed by swelling in the medial part of the joint, pain and difficulty in putting weight on the foot. All were examined by a doctor who prescribed rest and a bandage. None of the ankles were immobilized in plaster. At first the injury seemed to heal and the patients took up their sports activity again. However gradually a relapse occurred with repeated periods of medially localized pain and swelling. At last a permanent state of insufficiency occurred, forcing the patients to give up their sport entirely. As a rule the patients managed to walk and run on even ground

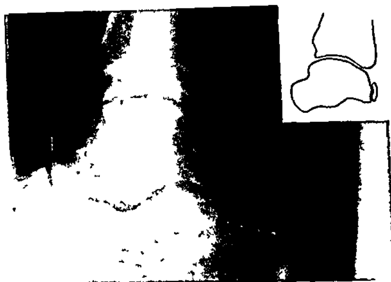


Figure 4 Small bone fragment in the right ankle (football player, aged 20)

but could not manage more demanding exercises like running on uneven ground making a sudden change of direction or stopping short when running, tackling an opponent or kicking the ball, etc As a rule the state of permanent insufficiency developed over a period of about a year or more after the original injury

The clinical examination revealed the occurrence of an obvious swelling behind the medial malleolus with a blotting out of its normal contour and a palpable rounded, bony and most often tender formation corresponding to the talus Otherwise, the ankle was painless and had a normal mobility and stability

Radiographic appearance

Roentgenological examination of the ankles of the four patients showed the occurrence of a bone fragment of varying size situated medially and dorsally to the talus (Figures 3 and 4) Repeated examinations of one patient showed a transformation from several small and faulty mineralized bone fragments to one large and rather highly mineralized bone fragment indicating the formation of callus or even new bone (Figures 5 and 6) In this case a fragment hed in the talus was diagnosed as well

Operative findings

Three patients were operated on A short curved skin incision was made across the bony formation behind the medial malleolus Access to the medial tubercle of the talus was accomplished by dissection between the tendon of the long flexor muscle of the toes and the tendon of the long flexor muscle of the big toe (Figure 7) In all the patients a rather loose bone fragment was found, surrounded by



Figure 5



Figure 6

Figures 5 and 6 Right ankle of a football player aged 2› In 1971 (Figure 5) Several small bone fragments In 1972 (Figure 6) One large bone fragment and visible fragment bed in the talus

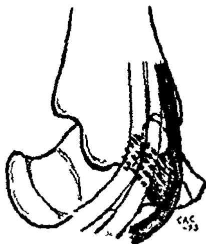


Figure 7 Schematic drawing showing the position of the avulsion fragment belonging to the medial tubercle of the talus

fibrous tissue and belonging to the talus The bone fragment showed characteristics of a real pseudarthrosis i e the fracture surface was covered by a layer of cartilage and supplied with marginal osseous deposits The bed of the fragment was situated just in front of the sulcus of the long flexor muscle of the big toe The size of the bone fragment was about 0 5 × 1 × 2 cm in one patient a little larger (Figure 8) The bone fragments were extirpated because a reconstruction of the ligament seemed to be unrealistic considering the narrow and scarred circumstances locally The size of the bone fragments was altogether much larger than the roentgenological examination indicated Their size however was in good agreement with the clinical examination

RESULTS

The observation time was ½ 3 years All the patients took up their sports activity without restriction within three months after the operation and had no residual symptoms

DISCUSSION

Isolated rupture of the posterior talotibial ligament is, with all probability, a very rare ankle injury The author has not found mention of this ligament rupture in the literature previously The four cases that

Figure 8 Bone fragment extirpated Incision behind the medial malleolus (same patient as Figure 4)



have been reported in this paper were, strangely enough, met with in active sportsmen It is not known if this injury is found in sportsmen only though it is not improbable as, by experience, they often expose their ankle ligaments to a heavy burden The injury has, however not been given attention in literature on sports injuries, either (for instance Blazina & Westover 1965) Of course anybody can suffer a heavy dorsal extension and pronation trauma to the ankle, for instance when slipping or on making a false step on uneven ground Perhaps the injury heals to such an extent that the ligament, so to speak, stands the burdens of everyday life

The ligaments of the ankle very seldom rupture with the avulsion of bone fragments from their origin or insertion (Brostrom 1966, Cedell 1967) Instead, most of the ruptures appear in the very ligament itself Contrary to the so called ligamentous fractures these ligament ruptures only very seldom present any healing problems The bone fragments on the other hand often show healing disturbances and most of them probably only heal by fibrous union with the risk of remaining un stable and hence resulting in a relapse of the symptoms With all probability all the patients in this material sustained such a ligamentous fracture of the talus, followed by a pseudarthrosis Knowing that only a minority of the ruptures of the ankle ligaments are combined with bone fragments one can directly conclude that an injury to the

posterior talotibial ligament may not be as rare as it seems to be. Our very rare diagnosis of this ligament rupture may, among other things, depend upon the good prognosis of the injury and on the fact that the posterior talotibial ligament, in contrast to the anterior talofibular ligament, is not very important for the stability of the ankle joint.

SUMMARY

Isolated rupture of the posterior talotibial ligament is probably a very rare injury. The author has diagnosed this ligament injury in four sportsmen, who had a chronic state of insufficiency with medial pain and swelling in the ankle joint. Clinical examination revealed the occurrence of a bony and tender formation behind the medial malleolus which at operation was found to be an unhealed avulsion fragment belonging to the medial tubercle of the talus. All the three patients operated on could after fragment extirpation take up their sports activity without restriction.

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MALFORMATIO CONGENITA ARTICULI TALO-CRURALIS

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Accepted 17 ix 73

Congenital rigid flat foot (CRF) is a very uncommon condition diagnosed even more rarely in the newborn and infants In some cases the diagnosis is first made when the child begins to stand The reason for this relatively late diagnosis is that flat feet in babies is a frequent finding and only seldom requires treatment This holds true only for the statical group of plano-valgus feet, which in children under three years of age may be considered as physiological These exhibit free movement in both the ankle and subtalar joints

CRF in the newborn is a serious deformity which is very difficult to treat The diagnosis must be made as early as possible, preferably within the first weeks of life since a good result relies on immediate commencement of treatment (Giannestras 1967). These children have free movements in the ankle joint, but their subtalar joints are fixed

In the literature studied on CRF it has been shown that these children have a vertical talus with dislocation of the talo-navicular joint and prominence of the head of the talus into the sole of the foot medially The calcaneus is pulled up posteriorly, the metatarsus is dorsiflexed and the foot is in a position of valgus deviation The angle between the talus and the calcaneus viewed from the side (tcs-angle) is large, and the angle between the same two bones viewed anteriorly (tca-angle) is large too There is no alteration in the talo crural joint

One can reasonably understand why CRF is also called backward clubfoot when these deformities are compared with those of the congenital equinovarus deformity where the tcs and tca deviations are small, and where the head of the talus projects more or less laterally in comparison with the navicular bone (Osmond-Clarke 1956)

In some children with congenital clubfoot Fjeldborg (1971) has found a slight widening of the medial malleolus, but otherwise no abnormalities of the talo-crural joint. In other cases of congenital clubfoot in children Hjelmstedt (1973) has described differing flat-

Figure 1 The propositus's feet from the front

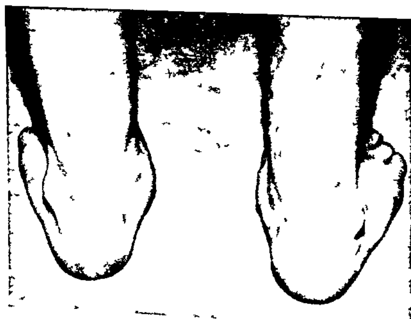


Figure 2 The propositus's feet from behind

tening of the trochlea tali, obliteration of the ankle joint's recesses with reduction of the trochlear joint surface, and finally changes in the medial and lateral facets of the talus.

In a Danish family, I have found CRF combined with a previously undescribed congenitally inherited deformity of the bones which make up the ankle joint. Changes are found mainly in the ankle joint, but the joints between talus and calcaneus, and the joint between talus and the navicular bone are affected too in several cases.

In the following, the characteristic clinical and radiological appearances of the deformity are described, and it is shown how it presents itself at different ages. Finally, a family tree is shown. This has been worked out after personal reference to all surviving members of the family.

CASE REPORTS

The propositus (III, 22) was born on 4/7 1949 and prior to his presenting symptoms he had been a fit farmworker. At 23 years of age he was referred to the orthopaedic department in Aalborg because of weightbearing pain in both feet over many years He is the third of four children The mother had been well during the pregnancy and took no medicines. His parents are related only by marriage.

At the objective examination it was found that the patient's gait was normal His feet were flat both with and without weightbearing. The toes were normal. The lateral malleolus was prominent. There was an obvious prominence on the inside of the foot just distal to the level of the medial malleolus (Figures 1 and 2). Movements in the talo-crural and subtalar joints were much reduced. With both straight and flexed knee there was only oscillatory movement around the neutral position in the talo-crural joint, whilst there was only a few degrees of pronation and supination in the subtalar joints Clinically, there was consequently a fixed flat foot with a practically stiff ankle joint

No other congenital abnormalities were found, especially in the bones and joints. The patient was mentally normal

X-rays of the feet show deformities of the tibia, fibula and talus with the following changes in the ankle and subtalar joints (Figures 3 and 4). In the A-P projection, the tibia appears short compared to the fibula, the medial malleolus is greatly hypoplastic with the whole of the vertical portion missing The lateral malleolus is thickened thus protruding to a considerable extent both medially and laterally. The talus is widened medially and the vertical joint surface which normally articulates with the medial malleolus is absent Laterally the talus is excavated corresponding to the medial prominence of the lateral malleolus. The ankle joint seen frontally is thus changed from the normal hinge to a joint composed of a horizontal medial portion and a U-formed vertical lateral portion

From the side, the distal extremity of the tibia is widened posteriorly by a bony process and the normal concave joint surface is changed to an anterior concave with a posterior convex curve stretching completely to the posterior edge of the tibia.



Figure 3 Right ankle and hind foot of the propositus (III 22)



Figure 4 Left ankle and hind foot of the propositus (III 22)



Figure 5 Right ankle and hind foot of the propositus's mother (II 9)

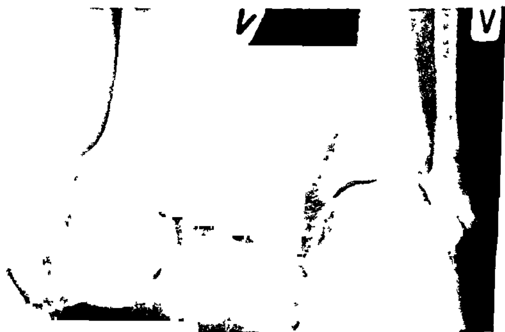


Figure 6 Left ankle and hind foot of the propositus's mother (II 9)



Figure 7 Right ankle and hind foot of the propositus's sister (III, 24) at the age of 19 years

Both the body and neck of talus are deformed the body being high and short whilst the posterior process of the talus is large and solidly combined to the body Proximally the joint surface is curved corresponding to the tibial surface and extending completely out onto the posterior process The neck of the talus is also short and the talus stands upright but not vertically There is no dislocation between talus and the navicular bone The joints between talus and calcaneus are not clearly seen probably due to the medial and distal displacement of the talus compared to the calcaneus Extra projections plus tomography were taken which were unsuccessful in showing a clear picture of the subtalar joints It is unlikely that a bony bridge exists between the two bones and there are definitely no bony bridges between other tarsal bones

X rays of the lumbar spine the pelvis the hips, femora the knees and hands were taken all of which showed normal structure Chromosomal studies were normal

The propositus's mother (II 9) was born on 25/7 1915 and was in her youth, examined in the orthopaedic department because of symptomatic flat feet No X rays were taken at that time At 58 years of age she was again referred to the department for examination because of weightbearing pain in her feet The symptoms were so severe that the patient had in fact applied for a full pension She has been a good observer of the family's defect, and she knew that her father had deformed feet of the same type as herself and other members of the family

With clinical examination it was found that both feet were flat and fixed and the ankle joints were practically stiff like the propositus Figures 5 and 6 show



Figure 5 Right ankle and hind foot of the propositus s mother (II, 9)



Figure 6 Left ankle and hind foot of the propositus s mother (II 9)



Figure 10 Right and left ankle and foot of the propositus's cousin (III, 1) at the age of 6 years

symmetrical changes of the talus and in and around the ankle and subtalar joints The changes were the same as her son's but less marked The upright talus with the short neck was clearly seen The subtalar joints were shown better than in the propositus There were some slight arthritic changes in the talo crural joints but not in the subtalar joints Heel spurs were seen on the calcaneal tuberosities

The propositus's sister (III, 24) was born on 14/1 1951 She had both clinically and radiologically the same type of changes as her mother and brother, but here again the changes were less marked than in the propositus (Figure 7) X rays were taken when this patient was 13 years old The epiphyseal lines and centres are clearly seen (Figure 8) In the A P projection the tibial centre of ossification is hour glass shaped The fibular epiphysis is wedge shaped with the base lateral In the lateral projection the tibial epiphysis is at the anterior tibial edge where it is seen to be wedge shaped with the base anterior The wide talus is seen to project proximally to a considerable degree in the central part of the ankle joint

The last patient to be described is a male cousin of the propositus (III, 1), he was born on 4/4 1931 At the time of examination he was 38 years of age and had typical clinical and radiological changes in both feet (Figure 9) He was X rayed at 6 years of age revealing clear radiological abnormalities of both the distal tibial and fibular epiphyses (Figure 10) Both ossification centres are wedge shaped with the base to the periphery The wide talus and the short tibia are also seen No lateral views were taken at the same time

Figure 11 shows the family tree There are without doubt ten people possessing the described deformity The degree of manifestation varies within very narrow

Figure 8 Right ankle and hind foot of the propositus's sister (III 24) at the age of 13 years



Figure 9 Right ankle and hind foot of the propositus's cousin (III 1) at the age of 32 years

In this way the normal hinge joint is converted to a saddle joint (Figures 3 and 4) In the patients without this posterior process there is no possibility for this joint formation to occur (Figure 7)

It is clear that the severest and most obvious changes are found in the talo-crural joints, suggesting that the cause of the faulty development is a primary dysplasia of the distal tibial and fibular epiphyseal lines and centres The cause of such a primary dysplasia is not known, but in this connection it could be mentioned that the hereditary process for this deformity is the same as for chondrodystrophia foetalis

Finally, it is possible that the development of the ankle joint and talus as a whole is primarily abnormal so that there are, from the beginning, anatomical abnormalities in the *talus*, *the tibia*, and *the fibula*

The X rays of the feet and the ankle joints give a rational explanation of the limited movements in the talo-crural and subtalar joints The *erect talus explains the flat feet*

SUMMARY

After a short introduction on flat feet in the newborn, clinical and radiological description is given of a previously undescribed congenitally inherited deformity in and around the talo-crural joints Clinically there is a rigid flat foot with obvious limitation of movement in the ankle joints Radiologically there are changes in the talus, the tibia and the fibula The aetiology may be considered as a gene mutation The pathogenesis is discussed It can be a consequence of a mechanical influence on the distal epiphyseal centres of the tibia and fibula due to a primarily pathological centre of ossification of the talus together with an abnormally positioned talus with regard to the positions of the calcaneus and the navicular bone It may also be due to a primary dysplasia of the distal tibial and fibular centres of ossification Finally the condition could be due to a combination of these two mechanisms

The deformity *seems to be an autosomally*, dominantly inherited defect

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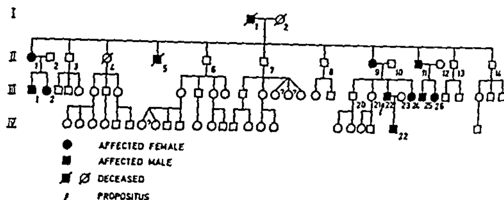


Figure 11. Pedigree

limits. The pattern of the family tree suggests that the condition is an autosomal dominantly inherited abnormality.

DISCUSSION

This inherited abnormality is presumably caused by a genetic mutation The time at which the mutation took place cannot be determined and the cause cannot definitely be established.

After careful study of the X-rays in Figures 8 and 9, where the epiphyseal lines and centres are distinct, one can formulate a hypothesis for the mechanism in the development of the anomaly It could be suggested that the high, wide, short, and erect talus is of primary consideration in causing the abnormality It can be postulated that the increased talus height can mechanically impede the growth of the distal tibial epiphysis thus explaining the relatively short tibia The wide talus, which is most prominent medially presumably presses the medial malleolus bud medially and proximally, thereby mechanically hindering the normal development of the malleolus The short tibia allows for medial expansion of the lateral malleolus bud, thus causing an indentation on the lateral side of the talus, the counterpressure of which could interfere with the fibular epiphysis The high talus can exert greatest pressure on the tibial epiphysis posteriorly, thus stopping the longitudinal growth earlier posteriorly than anteriorly At the same time the posterior tibial edge will be pressed backwards In patients with a large posterior process attached to the talus one can imagine that at an early stage of development of the foetus a kind of nearthron is developed posteriorly between the talus and tibia

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PLANTAR PROTRUSION OF THE METATARSAL HEADS

Conservative Treatment by a New Principle

Olov Lindahl & Henry Nilsson

Accepted 3 ix 73

The myth of the existence of an *anterior transverse arch* of the foot has persisted in international, and not least Swedish, orthopaedics for at least *half a century*, in spite of repeated indications to the contrary. It is mentioned, for instance, in the latest edition of Nordisk lärobok i Ortopedi (Iherton 1969) (Figure 1)

As long ago as 1930 Morton wrote "There is no such arch or arch conformation in this particular region of the foot, for each bone has direct contact with the ground through the intervening tissues" The same or similar views (Figure 2) have been presented by, among others Abramson (1927), Bankart (1935), Basler (1927), Bruce & Walmsley (1938), Elftman (1934), Jones (1941), Kelikan (1965) and Lake (1943) Kelikan (1965) pointed out the absence of a suitable designation or diagnosis for plantar dislocations of the metatarsal *heads seen in orthopaedic practice and often giving rise to corns and/* or intense pains on loading of the foot

Consistent with the erroneous hypothesis on the existence of an anterior transverse arch the conventional orthopaedic treatment has been an attempt to maintain such an arch, as is familiar to all orthotists orthopaedists and many patients This treatment consists in providing an anterior arch support, the purpose of this is to raise the three middle metatarsal bones by exerting pressure on them 2–5 cm behind the metatarsal heads, thereby producing an anterior vault with *the heads suspended* or in any case not involved in transmission of weight to the ground

In some mild cases this device can *help to relieve the pain, but* in many others it is worthless, and may even aggravate the discomfort by exerting pressure on an area not designed for loading While there is no anterior vault at the level of the metatarsal heads, further back

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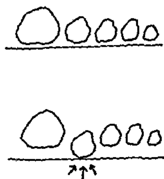


Figure 3 Above Normal anterior arch at the level of the metatarsal heads Below Protrusion of the second metatarsal head According to the authors (1973)

more In the disorders considered here the dorsiflexion of one or more of the heads (sometimes including the first and fifth) will stop before that of the others In such an overloaded area the pads will be exposed to such great pressure that they will atrophy, and inflammation and hyperalgesia is elicited The causal mechanism is thus a plantar contracture of at least one metatarsal bone in Lisfranc's joints in relation to the other metatarsal bones Theoretically, the metatarsal bone displaying plantar protrusion may be conceived as having a normal range of motion in Lisfranc's joints and the others as having a pathologically increased range of dorsiflexion but in practice this would seem unlikely We propose, however, that this disorder be designated *plantar protrusion of the metatarsal heads (protrusio capatis metatarsalis)* instead of pes transverso-planus/metatarsalgia The metatarsal heads that have a plantar protrusion will be responsible for transfer of the whole force between body and ground, while the others will retain their dorsiflexion mobility and hence assume little if any load

If it is assumed, firstly, that the transfer of weight from body to ground (except that *via* the heel) will be effected by the metatarsal heads 1 5 which with their pads are designed for this purpose, and, secondly that the pressure is distributed uniformly between the 4 lateral heads with a slightly greater weight on the first, it will be evident that in plantar protrusion of the metatarsal heads such a transfer will best be effected if the shape of the support for this region provides the desired distribution This means schematically that the support should be congruent with the loaded surfaces of the anterior part of the foot

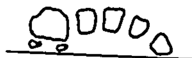




Figure 1 Above Normal anterior arch at the level of the metatarsal heads Below Pes transverso planus According to Nordisk larobok i ortopedisk kirurgi (1969)





Figure 2 Above Normal anterior arch at the level of the metatarsal heads Below The anatomic anterior arch in the zone between the proximal and middle third of the metatarsal bones According to Kelikian (1965)

there is an anatomic vault of the diaphyses of the metatarsal bones, which ensures that the muscles, tendons, vessels and nerves function unhindered by compression (Figure 2 below)

The anterior arch support will exert pressure within this region, and the resulting pain will not infrequently add to the patient's general misery, as will the discomfort of pinching shoes From an analysis of the mechanical conditions in the anterior part of the foot it is evident that there is a more effective way of relieving the load on the painful sites, including any corns

The depression of a metatarsal head that can be observed in such patients is illustrated in Figure 3 With normal function of the anterior part of the loaded foot it is obvious that the movements of the metatarsal bones in Lisfranc's joints are arrested by ligaments (and/or muscles) in full dorsiflexion, so that in normal cases the metatarsal heads 2–5 are loaded to about the same extent and the first one slightly

Figure 5 The negative impression



Figure 6 The finished sole



Figure 4. Impression of sole of foot under load

For the last 2 years this theoretical concept has been applied in practice by Nilsson, who is in charge of bandaging at the Department of Orthopaedics, Regional Hospital, Gavle An impression of the anterior part of the loaded foot is obtained in a special compound of clay and glycerin (Radings ortopediska AB, Södra vagen 10, Goteborg (article nr 9822)) (Figures 4 and 5) and from this a plaster cast is made. This is used to make a sole from calfskin and a plastic compound

RESULTS

The above procedure was used in 22 patients complaining of pains and/or corns in the metatarsal head region, who over a number of years had used an anterior arch support or worn conventional ortho paedic shoes After changing to this method for relieving the pressure, 17 of the patients reported a marked improvement or even complete relief and 4 some improvement only one found no improvement Many patients expressed the view that the system afforded the greatest relief for many years

DISCUSSION

Patients troubled with pain in the anterior part of the foot of the type considered here are often heard to complain that new shoes cause them discomfort for weeks or months until they have been worn in the pain is felt at plantar as well as dorsal and lateral pressure points Inspec tion of the old shoes invariably discloses small depressions in the sole corresponding to the metatarsal heads this bears out the logic of the form of treatment proposed here

In the case of pronounced plantar protrusion a correction is rarely obtained with the conventional anterior arch support A vicious circle results pressure on a point produces atrophy of the pads, inflamma tion and hyperalgesia and this leads to further difficulty in walking and tolerating weight on the tender metatarsal heads An operation is then often required By securing adequate relief of the load on these sites this circle is broken the reactive changes regress and the areas are gradually able to tolerate greater pressure A more uniform loading of all the metatarsal heads is then secured This relief from hyperalge sia and the reduction of tenderness on exposure to pressure are con firmed by the patients themselves

How is it that the conventional treatment consisting of providing an anterior arch support is sometimes effective and sometimes not? In the case of moderate overloading of any particular metatarsal head even the mild relief of the load obtained with a conventional support can lead to alleviation A theoretically deleterious pressure in the region of the metatarsal diaphyses is tolerated so long as it is not excessive In the case of pronounced plantar protrusion however relief is seldom obtained and the patient often continues suffering for the rest of his life most of which may well be spent in the seated position

Figure 7. Cross section at the level of the metatarsal heads during loading of the plaster foot, showing the close adaptation of the sole to the foot in the region of the protrusion.



(Podiasin, 3M Company, or Plastozote, AB Ribea, Box 10008 Stockholm) (Figures 6 and 7) The anterior part of this sole will be slightly more resilient than a leather sole but more rigid in the heel region, when this is built up with full support As the pain on loading is often quite troublesome the pressure is usually distributed over the whole of the sole, so as to minimize the average pressure on each part of the skin This means that the posterior vault of the foot is modelled to the positive plaster cast so that the region where an anterior arch support is normally allowed to press is included, and takes its share of the pressure

The sole is shaped to resemble an anterior arch support except that it bears the whole width of the foot and is not limited to the middle metatarsal diaphyses All the metatarsal heads are then involved in carrying the weight This sole is placed in an ordinary shoe or an orthopaedic shoe, depending on whether there are any other deformities of the foot, and as the sole is thicker than conventional ones (because of the depressions) a bigger last is needed

Acta orthop scand 45 481–489, 1974

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EFFECT OF PREVIOUS EXERCISE ON FRACTURE HEALING: A BIOCHEMICAL STUDY WITH MICE

EINO HEIKKINEN, TIMO VIHERSAARI & RISTO PENTTINEN

Accepted 15 x 73

Morphological, physical and metabolic changes occur in connective tissue during adaptation to physical exercise Prolonged physical training has been reported to thicken tendons and ligaments in growing rabbits (Ingelmark 1945), in young mice (Ingelmark 1948) and in dogs (Tipton et al 1970) Alterations in the elasticity of rabbit tendons have also been found (Viidik 1967, 1968), *suggesting that the number of* crosslinks is decreased by training (Viidik 1972) A direct relationship between ligament strength and the degree of mobilization of the knee joint has also been reported (Adam 1966) Muscle and bone hypertrophy is found in rats exercised by running (Saville & White 1969) The level of physical activity affects the turnover of collagen in long bones and achilles tendons of mice (Heikkinen & Vuori 1972) and the mineral and organic bone turnover in swine (Anderson et al 1971)

It is not known whether prior exercise affects tissue regeneration after an injury The present study was designed to establish the effects of previous training on the healing of experimentally produced fractures in mice

MATERIALS AND METHODS

A total of 150 two month old mice of the NMRI strain obtained from Ala Mankkaan tila Mankkaa Finland were divided into two groups Mice in group 1 were exercised daily on a treadmill with a progressively increased running program 30 minutes per day during the first week, 60 minutes per day during the second week and 2 × 60 minute periods per day during the third week at a speed of 30 cm/s Group 2 was kept under normal laboratory conditions. The animals *were fed* pelletted mouse diet (Manufactured by Hankkija, Finland) and fresh milk was available *ad libitum*

After the exercise period bilateral closed tibial fractures were produced manually

SUMMARY

The alleged existence of an anterior transverse arch in the foot is refuted with reference to the literature on the subject A mechanical analysis of the transfer of weight between the anterior part of the foot and the ground would seem to indicate that the pain and/or corns that sometimes arise under one or more metatarsal heads are due to plantar contraction in the Lisfranc's joints To alleviate this pain a new type of supporting sole is proposed, which is shaped to the loaded foot by means of a special casting technique The results obtained with this relief were good and the patients found the new shoes comfortable and definitely better than conventional orthopaedic shoes or anterior arch supports The designation *protrusio capitis metatarsalis* is proposed as a replacement for pes transverso-planus/metatarsalgia

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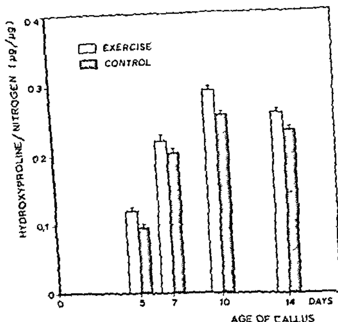


Figure 1 Effect of previous exercise on the ratio of hydroxyproline to nitrogen in tibial fracture calluses of mice All values are means of 8 10 calluses Each vertical bar represents the standard error of the mean Statistical significances of the differences were calculated by the analyses of variances

lanthanum chloride in 25 per cent HCl The DNA and RNA ribose content of the calluses was determined by the method of Schmidt & Thannhauser (1945) with some modifications (Penttinen et al 1972 c) For the measurement of total radioactivity an aliquot of 200 µl was transferred to a counting vial and 10 ml of a phosphor solution 6 ml of methycellosolve and 4 ml of POP POPOP solution) was added The radioactivity of hydroxyproline was determined according to the method of Prockop & Udenfriend 1961) as modified by Juva & Prockop (1966)

The statistical significances of the results were calculated by the analyses of variances or by the t test

RESULTS

Little difference was noted in the dry weight of the calluses from the two groups (Table 1) Tissue samples from the control mice contained more hexosamines hydroxyproline and total nitrogen at 5 days after the fracture Between the 7th 14th days the control calluses contained more nitrogen but approximately the same amount of hydroxyproline

Table 1 Dry weights (mg) and contents of hexosamine (μg), hydroxyproline (μg) and nitrogen (μg) of the 5–14-day-old fracture calluses in the exercised and control mice Statistical significances of the differences were calculated by the *t*-test

Days after fracture	Animal group	Dry weight	Hexosamines	Hydroxyproline	Nitrogen
5	exercised	6 0±0 4 (23)	60 0± 7 9 (8)	75 7± 6 9 (8)	654 1± 60 3 (8)
	control	7 3±0 3 (29)	105 1± 8 2 (10)	111 9± 6 1 (10)	1207 2± 81 1 (10)
	signif	$P < 0\ 001$	$P < 0\ 001$	$P < 0\ 001$	$P < 0\ 001$
7	exercised	7 4±0 5 (24)	193 6±14 8 (8)	133 9± 8 2 (15)	645 7± 60 7 (15)
	control	7 5±0 3 (29)	193 3± 6 4 (18)	136 7± 9 1 (19)	713 6± 38 5 (19)
	signif	NS	NS	NS	NS
10	exercised	13 2±0 7 (12)	433 2±28 7 (8)	323 7±20 6 (8)	1113 9± 70 4 (8)
	control	15 4±0 9 (20)	551 3±73 2 (10)	342 3±34 0 (10)	1357 2±148 8 (10)
	signif	NS	NS	NS	NS
14	exercised	21 0±1 00 (34)	289 9±30 5 (19)	383 1±23 1 (17)	1246 2±138 6 (17)
	control	22 3±0 8 (42)	305 8±20 4 (19)	355 6±14 4 (22)	1531 6± 60 3 (22)
	signif	NS	NS	NS	NS

Note – the means, their standard errors, the number of determinations and statistical significances of the differences are given (NS Non significant)

in both exercised and control mice The animals were killed at 5, 7, 10 and 14 days and the calluses were prepared and analyzed as described by Penttinen et al (1972 a)

To measure the rate of protein accumulation into the calluses [^{3}H L] proline (TRA 82, Radiochemical Centre, Amersham, England) 1 μCi/g, was injected intraperitoneally into mice 5 and 10 days after the fracture and the animals were sacrificed 1, 4, 8 and 24 hours later

Following lyophilization for 24 hours and drying in a vacuum desiccator to constant weight (dw) the calluses were weighed The samples were hydrolyzed in 2 N HCL at 103° for 16 hours Part of each hydrolyzate was removed for the determination of hexosamines Additional hydrochloric acid was added to the samples to a level of 6 N and the hydrolysis continued at 130° for 3 hours The hydrolyzates were evaporated dry on a boiling water bath the residues dissolved in distilled water and used for the determinations

Hexosamines were determined according to Blix s (1948) modification of the Elson Morgan method after removing interfering chromogens with a Dowex 1×50 cation exchange resin column (Boas 1953) *Hydroxyproline* was determined according to Woessner (1961) and *nitrogen* after combustion of samples in 8 N sulphuric acid according to Minari & Zilversmit (1963)

Calcium was determined with an atomic absorption spectrophotometer (Unicam SP 90, Unicam Instrument Ltd, Cambridge, England) in a 1 per cent solution of

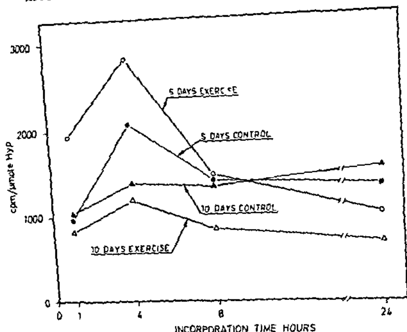


Figure 3 Effect of previous exercise on the incorporation of ³H proline into collagen ³H hydroxyproline in vivo in the 5 and 10 day fracture calluses

DNA was on the average 34 per cent higher in the calluses of the exercised animals (Table 2)

In addition the ratio of calcium to hydroxyproline was higher in the calluses of the exercised animals over a period 5 10 days after the fracture

DISCUSSION

The present chemical data suggest that previous exercise accelerates the sequence of fracture healing in mice Callus tissue develops faster as judged from the increased proportion of collagen to the total proteins (Figure 1), increased proline incorporation rates (Figure 3) and the concentrations of calcium (Figure 2) in the exercised callus The effects of exercise are most marked on the 5th and 7th days after the fracture which in the rat corresponds to the proliferation of *cartilaginous components* in the callus (Penttinen 1972 c) Exercised animals produced tissue which turned to bone more rapidly than the callus in the control mice Interestingly the size and mass of callus tissue was not increased

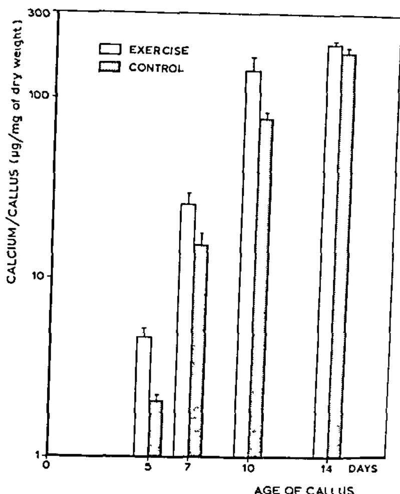


Figure 2 Effect of previous exercise on the amount of calcium in tibial fracture calluses of mice All values are means of 14–16 calluses Each vertical bar represents the standard error of the mean Statistical significances of the differences were calculated by the analyses of variances

(Table 1) The ratio of hydroxyproline to nitrogen (Figure 1) averaged 20 8 per cent higher in the calluses of the exercise animals ($P < 0\,01$)

On the 5th and 7th days the contents of calcium were 123 8 per cent and 67 7 per cent larger ($P < 0\,001$), respectively, in the calluses of the exercised mice (Figure 2). The incorporation of proline to collagen hydroxyproline on the 5th day was higher in the calluses of the exercised animals but on the 10th day lower incorporation rates were observed (Figure 3). The amounts of RNA-ribose were higher on the 5th and 7th days and the amounts of DNA on the 10th day lower in the calluses of the exercised group (Table 2) The ratio of RNA-ribose to

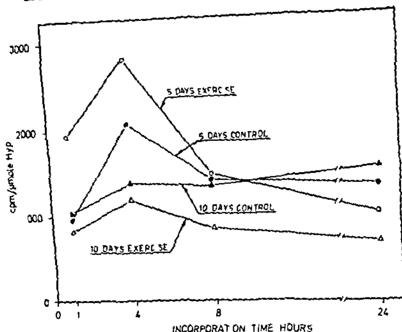


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in the exercised group The chemical properties of the repairing tissue are therefore important to the final result

Table 2 The contents of RNA-ribose (µg/callus) and DNA (µg/callus) and the ratio of RNA ribose to DNA in the 5–14 day old fracture calluses in the exercised and control mice Statistical significances of the differences were calculated by the *t* test

Days after fracture	Animal group	RNA	DNA	RNA ribose/DNA
5	exercised	76.1±4.5 (8)	26.0± 1.1 (8)	2.93
	control	61.4±4.8 (10)	27.8± 2.6 (8)	2.21
	signif	$P < 0.05$	NS	
7	exercised	82.5±2.8 (7)	33.8± 4.0 (7)	2.44
	control	75.5±2.9 (10)	41.2± 5.7 (9)	1.83
	signif	$P < 0.05$	NS	
10	exercised	138.0±7.2 (8)	190.1±12.8 (8)	0.73
	control	150.8±7.2 (10)	320.5±13.1 (8)	0.47
	signif	NS	$P < 0.001$	
14	exercised	93.7±6.3 (17)	142.0±13.1 (8)	0.66
	control	104.3±6.4 (19)	118.1±10.7 (10)	0.55
	signif	NS	$P < 0.02$	

Note – The means, their standard errors the number of determinations and statistical significance of the differences are given (NS Non significant)

Mechanisms which lead to altered capacity for bone healing in exercised mice are not known Numerous factors have been claimed to promote the regeneration of bone and some of them may have a correlation to physical activity These include secretion or administration of growth hormone (Nichols et al 1968, Hsu & Robinson 1969 Misol et al 1971, Koskinen et al 1971), or thyroid hormones (Tarsoly et al 1965, Koskinen 1967, Ewald & Tachdjian 1967, Ziegler & Delling 1972) and application of local electric currents (Cieszynski 1967, Becker & Murray 1967) The plasma concentration of growth hormone is reported to increase during exercise (Roth et al 1964, Hunter et al 1965)

Physical training increases the a-v-oxygen difference in skeletal muscles (Saltin et al 1964) Hyperbaric oxygenation of rats is known to increase the callus size, collagen content and mineralization (Coulson et al 1966, Yablon & Cruess 1969, Penttinen et al 1972 a) On the

other hand, hypoxia due to decreased atmospheric air pressure retards all parameters of the healing process (Penttinen et al 1972 b) It seems tempting to speculate that training facilitates the circulation in bone and callus and the transport function of the callus cells

The increased ^{3}H proline incorporation rates and the RNA ribose/DNA ratio suggest that the metabolism of callus cells is increased in the exercised animals This is supported by recent data on increased activities of some key enzymes of the Krebs' cycle and glycolysis in tendon and bone cells after an exercise period similar to that used in this study (Heikkinen et al unpublished results)

SUMMARY

We have studied the effect of prior physical exercise on the healing of leg fractures in mice Male mice were exercised for 3 weeks on a tread mill or kept under standard laboratory conditions After the training period tibias were fractured in both test and control animals Mice were sacrificed at 5 7 10 and 14 days after the fracture and the reparative callus tissue was isolated and analyzed The ratio of hydroxyproline to nitrogen in the calluses was on the average 21 per cent higher in the exercised mice The rate of synthesis of collagen and other proteins was greater at 5 days in the calluses of the exercised mice while calcium levels were strikingly higher The results suggest that fracture healing is hastened by previous physical exercise

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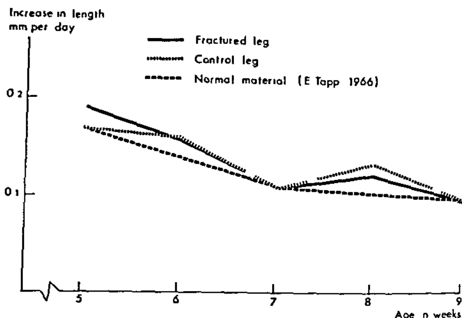


Figure 1 The growth of the proximal epiphyseal plate of the fractured and control tibiae The same figure shows the rate of growth in a group of normal rats

than in the other groups, taking place at a rate of about 5–15 degrees in four weeks against 5–10 degrees in four weeks in the other groups

Correction of the lateral angulation is illustrated in Figures 6 and 7, which show a series of X-ray pictures of two cases

Examination of the tetracycline-labelled specimens revealed that the longitudinal growth of the proximal tibial epiphysis had been asymmetric The growth on the concave side exceeded that on the convex side This finding was constant in both the valgus and varus deformity groups No significant correlation was found between the asymmetric epiphyseal growth and the amount of total correction or degree of angulation Increased apposition on the convex side of the metaphysis provided some evidence that the processes of resorption and apposition in the metaphyseal area were modified by the deformity These findings are illustrated in Figure 8

DISCUSSION

Angulation is always in one plane A slight change in projection in the X-ray examination causes an error in the measurement The influence of this factor on the results was determined in a series of pilot experiments by taking X-ray pictures of the malunited fractures, and

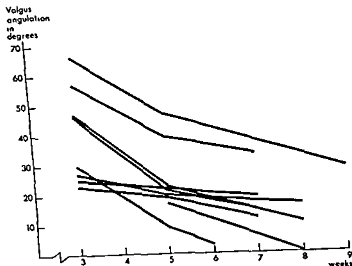


Figure 2

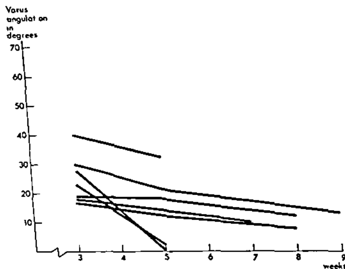


Figure 3

Figures 2-3. Correction of an angular deformity produced experimentally in the rat tibia. Angulation was measured 3-9 weeks after the fracture in X-ray pictures in two planes for the four different types of deformity.

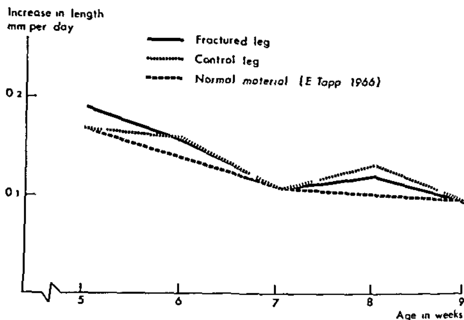


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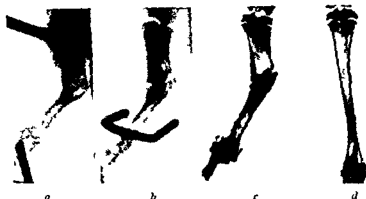


Figure 6 X ray picture of a rat tibia with a fracture consolidated in valgus a) three weeks b) five weeks and c) eight weeks after the fracture Control tibia on the right (d)



Figure 7 X ray picture of a rat tibia with a fracture consolidated in varus (a) three weeks b) five weeks and c) eight weeks after the fracture Control tibia on the right (d)

The failure to demonstrate stimulation of longitudinal growth does not accord with the generally accepted view that a diaphyseal fracture stimulates growth of the affected bone (Blount 1955, Sunden 1967) The relatively short time of observation and the retardation of growth in some cases with delayed union may explain this result This phenomenon is clearly illustrated in Figure 8 An additional study is in progress to elucidate the influence of non union on longitudinal

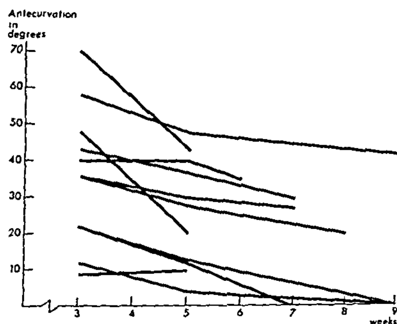


Figure 4

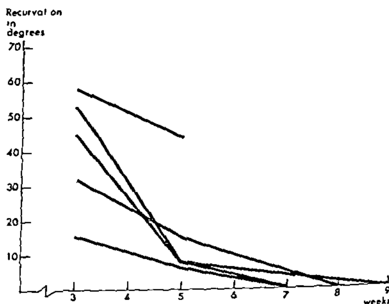


Figure 5

comparing the angulation found with the real angulation measured from the specimens It was noticed that the experimental error did not significantly influence the results when X ray pictures were taken with care under general anaesthesia



Figure 9 The corrective mechanisms possibly acting in the remodelling of the growing long bone
1) Local remodelling of diaphyseal deformity apposition and resorption
2) Metaphyseal remodelling resorption more intense on the concave side and less intense absent or substituted by apposition of new bone on the convex side
3) Asymmetric growth of the epiphyseal plate
4) A process comparable to that occurring in the metaphysis (2) may also take place in the epiphyseal plate and the epiphysis itself

series of experiments the importance of local remodelling by asymmetric epiphyseal growth and the change in the process of resorption and apposition in the metaphysis were confirmed

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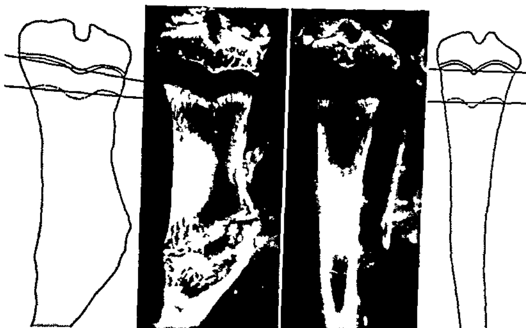


Figure 8 A specimen labelled with tetracycline Frontal plane section of a rat tibia with fracture malunited in valgus and labelled with tetracycline 14 days before killing photographed in ultraviolet light New bone apposition in the metaphysis on the convexity The line drawing depicts the asymmetric longitudinal growth (The borderline between the growth plate and the metaphysis as well as some other details are poorly seen in the black and white picture The measurements were made from colour films) Control tibia on the right Note the significant retardation of growth in the operated tibia probably caused by delayed union of the fracture

growth The case in Figure 8 also shows that asymmetric growth is independent of the stimulation of longitudinal growth The generally accepted view has been that increased pressure on the concave side results in retardation of growth (Evans 1957) However in experimental scoliosis it has been found that the number of cells on the concave side in the epiphyseal plate is increased and that growth takes place in the direction of the concavity (Karaharju 1967) This finding and the asymmetric epiphyseal growth do not accord with the law of Hueter Volkmann

Theoretically several factors may be involved in the remodelling process The diagram in Figure 9 shows the factors which in our opinion probably contribute to the remodelling process of the growing long bone This also serves as a working hypothesis for an experimental project designed to elucidate the various factors involved In this first

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DIURNAL VARIATION OF LONGITUDINAL BONE GROWTH IN THE RABBIT

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Accepted 18 xi 73

Earlier investigations have proved that there is a diurnal variation of the growth activity within different types of tissue (Messier & Leblond 1960 van Cantford & Barbason 1972) No such variation has been shown for the growth in length of the long bones, although a previous investigation has been performed with the tetracycline-method (Persson 1968 a) There are, however, indirect proofs of a diurnal variation With the colchicine method, the mitotic activity within the growth plate has proved to be highest during the light hours of the day (Simmons 1962, 1964) Also autoradiographic determinations with C^{14}-glycine, S^{35} and tritiated thymidine have given similar results (Simmons & McLean 1962, Simmons 1966, Simmons & Nichols 1966) In addition, radioimmunological determination of growth hormone in plasma of man has shown a diurnal pattern with high values at rest during the night (Hunter & Rigal 1966, Buckler 1970, Root 1972)

A closer investigation concerning the occurrence of diurnal variation in the rate of growth of the long bones seems to be desirable In the present investigation, this has been performed with the tetracycline method using multiple injections during a 24-hour period with 3 or 6 hours interval Short intervals increase the possibility of registering an oscillating growth pattern (van der Linden et al 1970)

MATERIAL AND METHODS

The material consists of 66 white rabbits (30 male and 36 female) from 12 litters, aged about 35 days at the beginning of the experimental period

They were kept together with their litter mates and mother both during the week before and throughout the experimental period, in a room illuminated during 06 00–

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C. 1 litter of 7 rabbits was given the same dose of OTC but 9 injections, with a time interval of 3 hours between each injection, the first at 12 00 and the last [illegible] later (litter 12)

investigation according to a previously described [illegible] longitudinal bone growth from the growth plate was determined between fluorescent bands corresponding to the injections of OTC (Hansson 1967) in the proximal tibia and fibula the distal tibio fibula, radius and ulna of the left side

RESULTS

The OTC-injections resulted in fluorescent bands within the metaphysis (Figure 1) The growth in length during the various periods was easily determined in the animals given OTC-injection with an interval of 6 hours (litter 1 to 11), it was more difficult to separate distinctly the fluorescent bands situated in the diaphyseal direction within the metaphysis in the group of animals (litter 12) given OTC-injections with an interval of 3 hours Therefore it was impossible to register the growth in length during all the time periods in the latter group

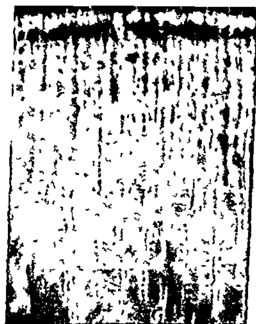
Table 1 Group A (litter 1 10) Longitudinal bone growth in per cent of mean value from all the growth plates during 6 hour periods 12 00–12 00 in various litters F value and its significance for the diurnal variation from analysis of variance in each litter

Litter	Number of animals	F value for time periods	Growth in per cent of mean value for all growth regions during the 6 hour periods			
			12 00 —— 18 00	18 00 —— 24 00	24 00 —— 06 00	06 00 —— 12 00
1	6	37 94***	104 3	95 0	98 4	101 4
2	4	56 29***	102 0	94 0	102 5	101 5
3	3	12 19***	96 4	100 0	102 6	101 0
4	4	36 00***	103 6	95 2	99 0	102 3
5	[illegible]	19 70***	98 2	97 5	104 4	99 8
6	5	26 71***	100 9	93 8	101 8	103 5
7	5	47 88***	94 1	94 1	104 5	107 3
8	7	33 11***	103 9	94.3	100 1	101 8
9	6	3 83*	101 6	99 0	99 9	99 5
10	7	79 30***	98 5	94 5	103 5	103 5
1 10	54	34 37***	100 4	95 7	101 7	102 2

*** $P < 0\ 001$ * $0\ 01 < P < 0\ 05$



Figure 1. Diurnal variation of longitudinal bone growth within the distal radius in the rabbit Injection of tetracycline 5 times with 6-hour intervals during a 24 hour period (06 00–06 00) The growth in length during the various 6-hour periods was found to be 93—86—79—95 microns (60 ×)



18 00 and in darkness the rest of the 24 period, except for the short intervals of about 5 minutes when the animals were given oxytetracycline–OTC (Terramycin®)

The following groups were used

A 10 litters of 54 rabbits in total were given 5 intravenous injections of 1 0 mg OTC/kg *with an exact interval of 6 hours* the first at 12 00 and the last 24 hours later (litter 1–10)

B 1 litter of 5 rabbits was given the same dose of OTC, the same number of injections with the same time interval, but beginning 06 00 during the 24 hour period (litter 11)

Table 4 Group B (litter 11) Longitudinal bone growth from different growth plates during 6 hour periods 06 00–06 00 F value and its significance for the diurnal variation from analysis of variance Calculation of percentage growth for the different 6 hour periods compared to the mean value for the 6 hour periods

th region	Growth in microns 6 hour period 06 00 —— 12 00	12 00 —— 18 00	18 00 —— 24 00	24 00 —— 06 00	Mean value for all 6-hour periods
ximal tibia	107±8	93±6	92±5	103±10	99
ximal fibula	84±7	72±10	72±7	80±10	77
al tibio fibula	90±10	79±8	78±8	84±11	83
al radius	91±3	80±9	78±6	89±8	85
al ulna	112±9	100±7	96±7	108±9	104
wth in % of mean ue for all growth ions	108 3 %	94 8 %	93 0 %	103.8 %	
122 39***					

$P < 0\,001$ Values = means ± standard deviations.

The combined analysis of variance for all the litters 1–10 is shown in Table 3 It was calculated by adding the values for mean square and for degrees of freedom from all the litters High F-values were found for all the different variables animals, growth regions and time periods Considerably lower F-values were found for the interactions between these variables The various litters differed considerably whereas no difference between the sexes ($P > 0\,05$) was found

Group B Also a highly significant diurnal variation (Figure 1) was found in Group B (litter 11), where the bone growth was registered 06 00–06 00 The bone growth was lowest 18 00–24 00, 93 per cent, and highest 06 00 12 00, 108 per cent of the mean longitudinal bone growth (Table 4) Thus, the variation was somewhat more pronounced in this group, but the growth registration was not performed during the same time period as for the litters 1–10 (Group A), but with a 6 hour displacement

Group C In those animals where the longitudinal bone growth was determined during 3 hour periods (litter 12), the variation of bone growth during the various parts of the 24 hour period of a day was found to be the same as for litter 1 11 animals As mentioned, it was impossible to make a precise quantitation of the bone growth during the whole experimental period in these animals

Table 2 Group A (litter 1–10) Longitudinal bone growth in per cent of mean value from the different growth plates during 6 hour periods 12 00–12 00 Mean value separate litter was added for each source of variation

Growth region	Mean value in per cent during 6 hour periods 12 00 —— 18 00	18 00 —— 24 00	24 00 —— 06 00	06 00 —— 12 00	Mean value in microns for all 6 hour periods
Proximal tibia	100 6	95 6	102 3	101 6	126
Proximal fibula	99 0	96 1	101 3	103 3	105
Distal tibio fibula	101 1	94 8	101 7	102 5	106
Distal radius	100 3	95 1	101 8	102 7	112
Distal ulna	100 8	97 1	101 3	100 8	131
	100 4	95 7	101 7	102 2	

Group A The statistical analysis of the results by analysis of variance (Tables 1, 2 and 3) showed that there was a variation of the longitudinal bone growth during the various 6-hour periods within group A (litter 1–10) (highly significant in 9 litters and almost significant in 1 litter) The rate of growth was lowest during 18 00–24 00 with an average growth rate of 96 per cent of the mean growth rate During the other periods, the longitudinal bone growth was percentagewise somewhat higher than the mean growth rate for all the 6-hour periods during 24 hours The variation was the same for the different regions and was also similar for most of the investigated litters (Tables 1 and 2)

Table 3 Analysis of variance of longitudinal bone growth in Group A (litter 1–10) Sum of squares and degrees of freedom from the analysis of variance in each separate litter was added for each source of variation

Source of variation	Sum of squares	d f	Mean square	F
Animals	40 591	44	922 5	56 49***
Growth regions	116 534	40	2913 4	178 41***
Time periods	16 837	30	561 2	34 37***
Animals × growth regions	7 926	176	45 0	2 76***
Animals × time periods	11 530	132	87 3	5 35***
Growth regions × time periods	4 481	120	37 3	2 29***
Residual	8 622	528	$16\ 3 = S^2$	
Total	206 521	1070		

*** $P < 0\ 001$

The amounts of OTC given at the injections had probably no influence, either stimulating or retarding, on the growth process (Hansson 1967). The moment for the beginning of the experimental period cannot reasonably have had any influence, as the corresponding diurnal variation in longitudinal bone growth was found in both groups (litter 1 10 and 11). There was, however, a somewhat different percentage variance of growth when these two groups were compared. This can be because the experimental periods were not identical and it is known that the rate of longitudinal bone growth per day in the rabbit decreases with increasing age in this age period (Hansson 1967). The error of method in the present investigation was found to be about 4 μ (Table 3). This is in agreement with earlier investigations (Hansson 1967) and cannot be responsible for the variations found in the present investigation.

In the present investigation, an obvious diurnal variation of the longitudinal bone growth during various parts of the day was found in most of the experimental animals. This agrees with the results from earlier investigations of mitotic activity in cartilage cells and production of matrix within the growth plate in the mouse and rat (Simmons 1962, 1964, 1966; Simmons & McLean 1962, Simmons & Nichols 1966). The reason for the smaller diurnal variation found in the present investigation might be that the mineralization process, registered with oxytetracycline, follows 1–3 days after the production of cells and matrix within the growth plate (Walker & Kember 1972). Furthermore, the species of the experimental animals is different. In the earlier investigations, the mitotic activity and the production of matrix within the growth plate were found to be higher during the light hours of the day than during the dark hours. A somewhat similar diurnal variation for the endochondral calcification process was found in the present investigation. This variation was most obvious for the evening period (lowest 18.00–24.00) compared to the rest of the day. Thus, the great diurnal variation during the proliferative phase of the cartilage cells decreases as the cartilage cells mature during the hypertrophic and degenerative phases when the intercellular matrix is calcifying. This diurnal variation results in an oscillating growth curve with the lowest rate during the evening hours.

SUMMARY

Diurnal variation in the growth process of the long bones was investigated with the tetracycline-method in 66 5-week old rabbits.

DISCUSSION

In earlier investigations of the growth in length from the growth plate of a long bone with the tetracycline-method, the registration has usually involved 24-hour periods (Hansson 1967, Sunden 1967, Persson 1968 b, Hedstrom 1969) or 12-hour periods (Persson 1968 a). As the present investigation shows, the bone growth could easily be registered during 6-hour periods. It was possible to use 3-hour periods, but that made the growth registration during the 24 hours difficult. This was partly due to the earliest fluorescent bands being displaced so far down into the metaphysis that they were somewhat weakened by the process of resorption therein. Furthermore, the remaining parts of the band were covered by bone tissue containing tetracycline formed in the endochondral ossification process. In some cases, the fluorescent bands lay too close to each other and could not be seen distinctly.

The statistical treatment of the material (litter 1-11) with an analysis of variance showed a highly significant diurnal variation of the longitudinal bone growth in 10, and an almost significant variation in 1 out of 11 litters. The diurnal variation was similar within the different growth regions. This diurnal variation seems real. The OTC-injections were given at the exact time indicated, and within the same litter, the animals were given the OTC-injections in the same order at each injection occasion. The animals were well-conditioned to their surroundings at the beginning of the experimental period, having being kept together with their mothers and litter-mates under these conditions for one week. The short period of illumination that the animals were exposed to in association with the injections at night probably had no influence on the registered diurnal variation of growth.

The analysis of variance also showed high F values for the variables animals and growth regions (Table 3) indicating great differences. These differences are well known from earlier investigations (Hansson 1967). Considerably lower F-values, but highly significant variance, were found for the interactions between the different variables. These differences, however, might be explained by the differences in growth rate between the litters and between different animals and growth regions. The rate of longitudinal bone growth is known to have a specific growth curve for the different growth plates, the rate of longitudinal bone growth being generally higher at a younger age (Hansson 1967).

The amounts of OTC given at the injections had probably no influence, either stimulating or retarding, on the growth process (Hansson 1967) The moment for the beginning of the experimental period cannot reasonably have had any influence, as the corresponding diurnal variation in longitudinal bone growth was found in both groups (litter 1–10 and 11) There was, however, a somewhat different percentage variance of growth when these two groups were compared This can be because the experimental periods were not identical and it is known that the rate of longitudinal bone growth per day in the rabbit decreases with increasing age in this age period (Hansson 1967) The error of method in the present investigation was found to be about 4 μ (Table 3) This is in agreement with earlier investigations (Hansson 1967) and cannot be responsible for the variations found in the present investigation

In the present investigation, an obvious diurnal variation of the longitudinal bone growth during various parts of the day was found in most of the experimental animals This agrees with the results from earlier investigations of mitotic activity in cartilage cells and production of matrix within the growth plate in the mouse and rat (Simmons 1962 1964 1966, Simmons & McLean 1962, Simmons & Nichols 1966) The reason for the smaller diurnal variation found in the present investigation might be that the mineralization process, registered with oxytetracycline, follows 1 3 days after the production of cells and matrix within the growth plate (Walker & Kember 1972) Furthermore the species of the experimental animals is different In the earlier investigations, the mitotic activity and the production of matrix within the growth plate were found to be higher during the light hours of the day than during the dark hours A somewhat similar diurnal variation for the endochondral calcification process was found in the present investigation This variation was most obvious for the evening period (lowest 18 00 24 00) compared to the rest of the day Thus, the great diurnal variation during the proliferative phase of the cartilage cells decreases as the cartilage cells mature during the hypertrophic and degenerative phases when the intercellular matrix is calcifying This diurnal variation results in an oscillating growth curve with the lowest rate during the evening hours

SUMMARY

Diurnal variation in the growth process of the long bones was investigated with the tetracycline method in 66 5 week old rabbits

The growth from five different growth plates was determined during 6 hour periods covering 24 hours. Experiments with intervals of 3 hours were also performed, but the growth determination was difficult. The determination showed a small but statistically highly significant variation of the longitudinal bone growth during various parts of a 24 hour period. A diurnal variation in the longitudinal bone growth was found with the lowest growth rate during the evening hours.

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RESULTS OF TREATMENT FOR ANTERIOR RECURRENT DISLOCATION OF THE SHOULDER JOINT WITH THE EDEN-HYBBINETTE OPERATION

T Sam Lindholm

Accepted 1.xi 73

This study describes the follow-up results of a series of patients operated on for anterior recurrent dislocation of the humero-scapular joint using the Eden-Hybbinette technique and followed postoperatively by early mobilization of the upper extremity

Operative Technique and Postoperative Treatment

A ventral incision was made distally from the coracoid process The interval between the pectoralis major and deltoid muscles was opened The cephalic vein was protected The subscapular tendon was divided near its insertion into the neck of the humerus The joint capsule was opened and the glenoid rim identified A transplant measuring about *1 5–3 cm in breadth and length was taken from the anterior iliac crest* After trimming to a T or V shape it was placed intra-articularly in a subperiosteal pocket made with a chisel in the glenoid rim in a ventro-caudal position A part of the transplant measuring 0 5–1 cm protruded above the joint surface The joint capsule was duplicated and the subscapular tendon was as a rule shortened The wound was closed in layers

The upper limb was immobilized to the wall of the chest with a Velpeau bandage for one or two weeks and then changed to a mitella Two weeks after the operation pendular movements of the extremity were allowed Three weeks postoperatively abduction movements were commenced under the guidance of a physiotherapist Five weeks postoperatively all movements were allowed

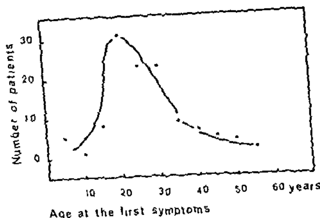


Figure 1 The first symptoms of dislocation occurred in two thirds of the patients between 16 and 30 years about one half of these being between 16 and 25 years

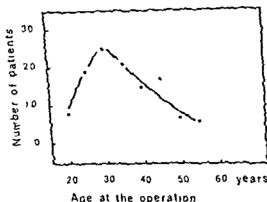


Figure 2 Approximately two thirds of the patients were operated on before the age of 36 The youngest patient was 16 and the oldest 56

MATERIAL

The series consisted of 118 patients with 124 anterior recurrent dislocations of the gleno humeral joint operatively treated at the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland during the years 1945–1971 The 118 patients were made up of 90 males and 28 females The right shoulder was involved in 64 cases and the left in 44 There were 8 cases with a bilateral dislocation 6 in males and 2 in females The males had 45 unilateral dislocations on the right side and 36 on the left the females, 19 on the right and 8 on the left

The age distribution patterns of the treated patients at the onset of the symptoms of the dislocation the age at the time of the first operation and the interval between the symptoms and the first operation are seen in Figures 1–3

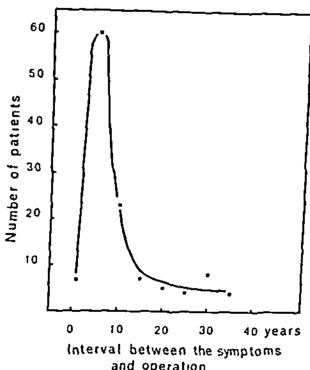


Figure 3 The interval between the first dislocation and the operation was between 1 and 5 years in half of the patients and between 1 and 10 years in two thirds

Trauma was the cause of the first dislocation in 77 shoulders In 52 of these the dislocation was attributed to a direct injury to the shoulder, in 21 to a forced movement and in 4 to a combination of these The dislocation was spontaneous in 47 shoulders In 2 of these the glenoid fossa was congenitally abnormal

The frequency of recurrent dislocation (101 shoulders) in relation to age at the onset of symptoms is seen in Table 1

The dislocation had been primarily reduced by a doctor in 40 cases mostly without anaesthesia In 56 cases the patient himself or a layman had reduced it In the remainder of cases the situation in this respect was unclear

The duration of immobilization after the first reduction was less than 3 weeks for the majority of patients, only in three cases did the duration exceed 3 weeks

Before the operation, redislocation caused discomfort or pain in 94 shoulders There were no complaints in 30 shoulders The mobility of the shoulder joint was preoperatively good in 106 shoulders, fair in 12 and poor in the remainder (due to muscle weakness in 4 shoulders and a plexus lesion in 2)

In the preoperative X-ray examination (taken with the arm in inward or outward rotation) the typical defect in the postero-lateral part of the humeral head was noticed in 42 shoulders, and a fracture of the anterior rim of the glenoid in 27 shoulders.

The technique described above was the first operation carried out for recurrent anterior dislocation in 104 unilateral and six bilateral cases There were in addition eight cases who came to our hospital for reoperation Reoperation was undertaken in five of these after an earlier soft tissue operation (capsulorrhaphy) with

redislocation of the joint and was regarded as necessary after a bone block operation in three cases before loosening of the transplant In one of these an Eden Hybbinette operation had been performed twice at another hospital at an interval of five months and a third one was now undertaken because of redislocation The transplant worked loose in this case too and arthrotomy and extirpation of the transplant were performed The capsule was duplicated and the subscapularis shortened

Table 1 The frequency of recurrence in 101 shoulders is more pronounced in the younger age groups especially under 20 years The patients could not remember the number of dislocations for 23 of the 124 shoulders

Age at the first dislocation of the shoulder (years)	Number of recurrences in 101 cases			
	< 10	11 20	21–30	> 30
< 10	5	4	5	10
11 20	8	8	6	23
21 30	10	5	3	[illegible]
31 40	3	1		1
41 50	2			
	28	18	14	14

A questionnaire concerning the postoperative state was sent to all of the patients 93 of the patients answered it. Those patients with poor mobility of the shoulder joint postoperative redislocations and those reoperated because of detachment of the bone graft were clinically re examined In the other cases the available data in the records were used More than half of the patients were observed for 6 years and one fourth of 11 years postoperatively For 93 of the patients the age at follow up was between 21 and 50 years

RESULTS

The results of the questionnaire and the re examinations are seen in Table 2 The general condition of the shoulder joint was good in 111 cases Joint mobility was normal or fair in 118 and gave *no pain in* 79 In the clinical examination during the follow up time it was noticed that flexion was impaired in 22 shoulders abduction in 11, inward rotation in 9 and outward rotation in 28 The joint had been redislocated in 2 cases once in one case twice and in two cases more often postoperatively

Observations concerning the shoulders with postoperative redislocation may be summarized as follows

Table 2 The functional result of the operated shoulder joint according to the questionnaires and the follow-up examination

General Condition of the Shoulder	
good	111
fair	9
poor	4
	124
Pain in the Shoulder	
upon movement	18
at rest	4
both	23
no complaint	79
	124
Mobility of the Shoulder Joint	
normal	81
fair	37
poor	6
	124
no redislocation	119
redislocated	5
	124

A 60-year-old male had a dislocation 4 years postoperatively after trauma to the shoulder In X-rays the transplant was in place but fragmented

A 57-year-old male had 5 redislocations the last being about 20 years after the operation X-rays revealed that the glenoidal surface was flattened and that there was a defect in the postero-lateral surface of the caput humeri The transplant was in place

A 55-year-old male had one redislocation postoperatively probably as a result of a trauma X rays showed that the transplant was in position

Figure 4 Postoperative radiographs of shoulders showing different conditions of the bone transplants A fused B fused but with distal resorption C fully resorbed, D fractured and fragmented E not fused but attached by a fibrous bone connection, F the transplant has fused but there is an area of resorption around it and the distal part is probably loose


A
B
C
D
E
F

A 52-year-old male had many redislocations postoperatively. He was operated on 15 years previously. X-rays revealed that the transplant was loosened.

A 27-year-old female treated operatively 8 years previously had two redislocations which she reduced herself. In the X-rays the transplant is in place and consolidated. The cause of the redislocations is unknown.

In the postoperative X-ray follow-up the bone transplant was in place and consolidated in 109 shoulders. In 4 the transplant was partly resorbed distally and in 3 fully resorbed on an average one year after operation. The transplant was partly loosened in 4 shoulders on an average 3 years postoperatively and in another 4 it was fully loosened on an average 7 months postoperatively. The postoperative state of bone transplants is shown in Figure 4.

In 10 cases there were prominent osteoarthritic changes in the joint and in 5 myositis ossificans round the joint.

DISCUSSION

Recurrent dislocation is more frequent in the shoulder than in any other joint. The dislocation may be of a traumatic, habitual or congenital type. The cause of the recurrence depends on several factors, such as the age of the patient (Rowe & Sakellarides 1961), the site and nature of the primary injury (McLaughlin & MacLellan 1967) and the length of immobilization after the initial dislocation.

Anterior recurrent dislocation has been treated in the main with 3 types of operative techniques, i.e. transfer of tendons in the shoulder joint, e.g. the long head of the biceps tendon (Nicola 1929), subscapularis, the Putti-Platt operation (Magnuson & Stack 1943, Osmond-Clarke 1948) reattachment of the capsule (Bankfort 1938, du Toit & Roux 1956, Boyd & Hunt 1965) and bone block operations (Eden 1918, Hybbinette 1932, Palmer & Widen 1948). In Finland the latter operative technique or the Eden-Hybbinette operation has proved very useful (Langenskiold 1939, Hublin 1946, v. Hellens 1947, Solonen & Rokkanen 1972).

The operations of this series of patients were performed by a great many surgeons. Reoperation according to Eden-Hybbinette was performed in five cases after a soft tissue operation with postoperative redislocation, good results were achieved in four of these cases. In the fifth case arthrodesis of the humero-scapular joint was finally per-

formed for painful osteoarthritis Follow-up examination revealed re-dislocations in five cases In one case the redislocation was due to detachment of the bone transplant The redislocation in three cases must be attributed to trauma or a congenital disorder of the articular surface No explanation has been found for the postoperative redislocation in the fifth case It should be noted that the transplant has stayed in position in these four cases No postoperative redislocation has been established in the cases with resorption of the graft

It thus appears that postoperative redislocation occurred only in this case with a loose graft The recurrence rate after the Eden-Hybbinette operation was consequently 4 3 per cent at the follow-up Other materials report a recurrence rate of 15 per cent (v Hellens 1947), six per cent (Hublin 1946), one case out of 120 (Hindmarsh & Lindberg 1967), and five cases out of 95 (Solonen & Rokkanen 1972)

A *capsulorrhaphy* was also performed in conjunction with the block operation and as a rule a shortening of the subscapular tendon This explains to some extent why no redislocation occurred postoperatively despite the working loose of the fragment in some cases The local formation of scar tissue on the site of a transplant under resorption may also prevent recurrence Postoperative immobilization in a plaster cast has not been regarded as indicated instead, active postoperative mobilization in stages was used This procedure is also less unpleasant for the patient In addition, it gives in most cases a complete range of movement in the joint fairly quickly after the operation

Postoperative osteoarthritis was seen in only 10 cases of this material which is to be regarded as a low incidence The literature reports incidences ranging from 70 (Hindsmarsh & Lindberg 1967) to 11 per cent (Solonen & Rokkanen 1972)

The experience gained at this hospital is that our operative technique plus active postoperative mobilization give a very good outcome in the majority of the cases The technique may also be regarded as indicated in the cases in which earlier soft tissue operations have failed

SUMMARY

The results of the treatment of 124 anterior recurrent dislocations of the shoulder joint with the Eden Hybbinette operative technique are reported In the operation the iliac block was placed intra articularly and early mobilization of the extremity was emphasized Reoperation

with this technique after earlier soft tissue operations generally gave good results

Postoperative redislocations mainly caused by a new trauma occurred in 5 shoulders Resorption or loosening of the transplant was noted in 15 shoulders during the observation time

Only one redislocation was noted after the transplant had worked loose Some patients were restricted in flexion, abduction or inward or outward rotation of the shoulder joint postoperatively

The technique is recommended for the treatment of recurrent anterior dislocation even though reoperation by other methods has failed

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FRACTURES OF THE LATERAL CONDYLE OF THE HUMERUS IN CHILDREN

FLEMMING HOLST-NIELSEN & PAUL OTTSEN

Accepted 1 xi 73

Among fractures of the elbow during childhood those of the lateral condyle of the humerus make up almost one-fifth (Blount 1955) Today, the great majority of surgeons prefer operative treatment of these fractures, if they are appreciably displaced, without first trying closed reduction as recommended by Watson-Jones (1955) The difficulty consists in drawing the limit between fractures which one chooses to treat conservatively by immobilization in plaster without preceding reduction, and those which require open reduction and internal fixation

Blount (1955) warned against the tendency of even slightly displaced fractures of the lateral humeral condyle to secondary displacement in the course of conservative management Jeffery (1958) and Flynn (1971) pointed out that a number of fractures of the lateral humeral condyle with little displacement result in non-union, stating that the incidence of non-union is higher among the slightly displaced fractures than among the severely displaced ones—simply because *the latter are treated more adequately than the former*

The important question is whether it is possible to estimate with sufficient accuracy from the primary X ray films which fractures are stable and which are not

The avulsed fragment of the condyle, consisting of the capitulum

Figure 1 Fracture of the lateral condyle of the left humerus with external rotation of the capitulum Normally the axis of the capitulum drawn between the ulnar corner of the capitulum and the middle of its radial margin (a) is parallel to the epiphyseal line of the trochlea (b) or a few degrees internally rotated (In a smaller series of normal elbows the authors have found that the angle between (a) and (b) is always the same on both sides, even though the X ray projection has been altered up to 10° in any direction) (H = right V = left)





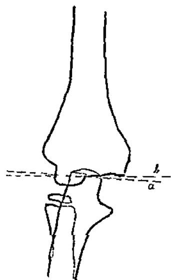


Figure 1 (H)

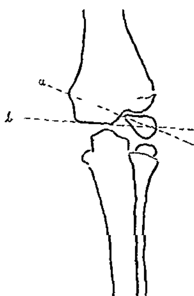


Figure 1 (V)

of the humerus with the adjacent part of the trochlea and a lateral chip of the metaphysis, is unstable when the aponeurosis from the common extensor muscles to the metaphysis is ruptured proximally to the fracture line. The first sign of such a rupture is rotation of the capitulum around the sagittal axis corresponding to the intact lateral collateral ligament (Wilson 1936, Watson-Jones 1955). This rotation may be minimal, but as the primary rotation takes place in the frontal plane it is disclosed by uniform AP X-rays of the fractured as well as unaffected elbow (Figure 1).

Thus, the primary displacement is definitely of decisive importance to stability and thereby to the risk of further displacement and possibly mal-union or non-union during conservative treatment. On the other hand, the possible causal relationship between mal-union and the disturbances of growth so common in the elbow after these fractures is still a matter of dispute (Wilson 1936, Salter & Harris 1963, Wadsworth 1964).

In an effort to elucidate further the relationship between the primary therapeutic results and the known late complications, a follow-up study was performed on a series of conservatively treated as well as operatively treated fractures of the lateral condyle of the humerus, of which all except one had shown some degree of primary displacement.

MATERIAL

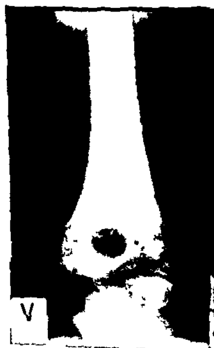
During the period 1955–1972 40 fractures of the lateral condyle of the humerus in children were treated 39 were seen at follow-up One patient living abroad could not be traced and was therefore excluded

Seven girls and 32 boys aged 2–13 years, average 6 5 years, had been treated. 15 fractures were on the right side and 24 on the left side From the case records it is impossible to state anything definite about the mechanism of the fracture in each individual case

In addition to the fracture of the lateral humeral condyle 9 patients had other injuries of the elbow, most often dislocation

The diagnosis and classification of the fractures was based upon the original X-ray films of the injured elbow compared with the opposite elbow in the two standard views, revised by the authors during the present study In the course of this critical revision of the primary radiographs one fracture was found to be in a good position, i e without any displacement, and 9 to be in a fair position, i e slightly displaced, viz laterally 2 mm or less, with no rotation These fractures were considered stable In the remaining 29 cases the position of the fractures was poor, viz showing more than 2 mm lateral displacement and in 25 of these cases also rotation of the capitulum These fractures we classified as severely displaced and unstable

Figure 2 Severely displaced fracture of the left lateral condyle which was not reduced Remodelling of the fracture at follow-up $2\frac{1}{2}$ years later Note premature calcification of the trochlear ossification centre on the affected side No angulation







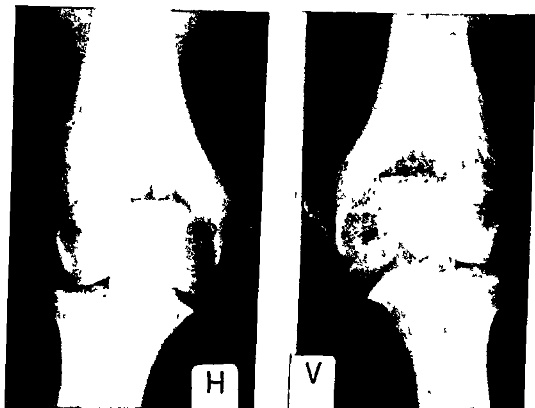


Figure 3 United left side fracture of the lateral condyle with overgrowth of the radial head as well as the capitulum of the humerus and fish tail deformity Carrying angle of 0°

METHOD AND RESULTS

No reduction had been performed in 19 cases In the original X-ray reports nearly all these fractures were described as showing no or negligible displacement Closed reduction had been carried out in 6 cases, and 16 fractures, including two which secondarily became displaced in the course of non-operative treatment, were treated by open reduction and osteosynthesis, using either catgut suture, metal suture, screw, nail, or Kirschner wire

After the primary treatment the position of the fracture was, as is apparent from Table 1, good in one-third of the cases, fair in one-third, and poor in one-third

Secondary displacement did not occur in the course of non-operative treatment of non-displaced or only slightly displaced fractures, but in 2 of the 15 severely displaced fractures which were first tentatively treated without operation In one of these cases the secondary dis-

Figure 4 Premature epiphysiodesis in a right side fracture of the lateral condyle of the humerus united in a good position 8 years after osteosynthesis No angulation





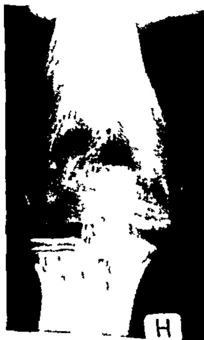






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Premature closure of the epiphyseal line of the capitulum of the humerus occurred in 6 elbow joints In 3 of these cases the fracture had healed in a good position (Figure 4) in the other three in a poor position There was no change in the carrying angle in three of the elbows after a follow up period of 6–10 years Of the remaining ones 2 resulted in a 0 degree carrying angle and one in a valgus deformity of less than 5°

In practically all cases in which the trochlear ossification centre had ossified at follow up there was a notch between the trochlea and the head of the humerus the so called "fish tail deformity This phenomenon occurred in well reduced as well as in poorly reduced fractures and may be due to deficient development of that part of the trochlea which is formed from the epiphyseal centre of the fractured capitulum (Wadsworth 1964) However the deformity was always



Figure 5 Right side fracture of the condyle reduced to a good position and fixed by a screw which just passes the epiphyseal line Twelve years later osteoarthritis developed because of healed osteochondritis dissecans in the capitulum of the humerus

Table 1 Results of primary treatment (X-ray findings)

Treatment	Position of fracture	Before treatment	After treatment	Secondary displacement
No reduction	Good	1	1	
	Fair	9	9	
	Poor	9	9	1
Closed reduction	Good	0	1	1
	Fair	0	3	
	Poor	6	2	
Open reduction and osteosynthesis	Good	0	13	
	Fair	0	1	
	Poor	16*	2	

* Including the two secondarily displaced fractures

placement occurred just over one week after closed reduction to a good position and in the other case more than 5 weeks after plaster immobilization of a fracture showing only a slight rotary displacement of the lateral condyle Both were thereafter successfully treated by open reduction and osteosynthesis

The mean period of immobilization for operated as well as non-operated elbows was 4 weeks Infection did not occur All fractures but one united within 4–6 weeks

FOLLOW-UP

All the patients were examined clinically and radiologically 1–17 years after the treatment, average follow up period 7 5 years

Although nearly one-third of the fractures had united in a poor position (Table 1), less than one-sixth exhibited a corresponding radiographic deformity at follow up Thus, a certain re-modelling of the *fractured condyle had taken place after union (Figure 2)*

A small bony prominence on the lateral aspect of the elbow was a common finding, and correspondingly the X ray films in 23 cases showed overgrowth in the *radial part of* the joint –usually of the radial as well as humeral *capitulum* (Figure 3) Nine of these elbows showed a varus deformity of up to 5° Most often there was a question *merely of a O-degree carrying angle* which the patient had not even noticed Only 2 of these 9 elbows had been treated by operation

Cubitus valgus was observed in 4 cases This deformity was 15° in *an elbow with non-union,* and less than 10° in the other three

the serious type IV injury (Salter & Harris 1963), and it is generally assumed that mal union often entails inhibition of growth in the lateral epiphysis and thereby a progressive cubitus valgus (Speed & Macey 1933, Wilson 1936, Jeffery 1958, Salter & Harris 1963) In the present material however, premature closure of the lateral epiphyseal line, like the 'fish tail deformity', occurred not only in cases that united with deformity, but equally often in cases where the fracture united in a good position Like Wadsworth (1964), the present authors do not believe that a good result of reduction and solid fixation affords any guarantee against these disturbances of growth On the other hand, we have encountered only a few, and clinically rather unimportant, cases of cubitus valgus in connection with premature epiphysiodesis of the capitulum and fish tail deformity Overgrowth radially in the elbow joint has been described by Blount (1955) as a consequence of delayed open reduction, whereas Hardacre et al (1971) found overgrowth to be in most cases a consequence of delayed union In our series overgrowth of the radial and humeral heads occurred in the majority of severely displaced fractures, regardless of the treatment Correspondingly, a mild varus deformity of the elbow was recorded more than twice as often as a valgus deformity

SUMMARY

Thirty nine fractures of the lateral condyle of the humerus were examined at follow up an average of 7 5 years after primary treatment It is suggested that condylar fractures showing more than 2 mm lateral displacement and/or external rotation of the capitulum be interpreted as unstable fractures and therefore treated by operation Ten stable fractures were treated conservatively with good results Among 15 unstable fractures which were treated primarily without operation, 2 became re displaced and one ended in non union Disturbances of growth in the elbow occurred independently of the treatment and the result of the reduction, but did not entail major deformities of the elbow

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most marked when the capitulum had united in rotary deformity and in cases with overgrowth of the lateral condyle (Figure 3)

The end results were assessed according to a modification of Hardacre et al.'s (1971) classification.

24 were good, i e without limitation of motion, without valgus or varus deformity, and without complaints

12 were fair, i e ≦ 15° extension or flexion defect or ≦ 10° valgus or varus deformity, no signs of osteoarthritis, no neurological symptoms, and no pain.

3 were poor, i e. > 15° extension or flexion defect or > 10° valgus or varus deformity or osteoarthritis, or ulnar neuritis or non-union or avascular necrosis of the capitulum or pain

The 3 poor results will be described in greater detail

Case 1 A 9-year-old boy with a severely displaced fracture and dislocation of the elbow was treated by closed reduction of the fracture as well as the dislocation Owing to secondary displacement of the fracture, operation was performed 8 days after the accident, and a good reduction was obtained At follow-up 10 years later there was ossifying myositis on the anterior aspect of the elbow joint and a flexion defect of 55°

Case 2 A 10 year-old boy with a severely displaced fracture was treated on the 6th day by open reduction and osteosynthesis using a screw Six years later radiography of the elbow showed osteochondritis dissecans in the capitulum of the humerus At follow-up 12 years later the osteochondritis had healed, but distinct arthritic changes were found in the joint (Figure 5) The patient had no pain, but an extension defect of 20°.

Case 3 A 9 year old boy with a severely displaced fracture was treated by closed reduction with a fair result 17 years later follow up showed non-union, an extension defect of 25°, and a valgus deformity of 15°

DISCUSSION

As was found by Hardacre et al (1971), really non-displaced fractures of the lateral humeral condyle were far less common in this material than displaced ones

Fractures showing slight rotary displacement can no doubt be treated conservatively as with non-displaced or only slightly displaced fractures However, this involves the risk of secondary displacement and non-union, and as a rule it is better to perform open reduction and osteosynthesis primarily, as a delayed operation may be difficult and may entail complications (Speed & Macey 1933, Blount 1955)

In Salter & Harris' classification of epiphyseal injuries in children, fracture of the lateral condyle of the humerus is a classic example of

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HANGMAN'S FRACTURE

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The first and second cervical vartebrae differ, anatomically and functionally, from the remainder of the cervical spine Half the rotation in the cervical spine takes place in the atlanto-axial joint, and a large part of the movement in the sagittal and frontal plane in the joints between the occipital bone, atlas, and axis (Werne 1957, Hohl 1964, Fielding 1964) At the same time the weight of the head is transmitted through the mobile cervical spine to the stable thoracic spine Traumas cause several characteristic injuries to the atlas and axis, including bilateral fracture through the neural arch of the axis According to Wood Jones (1913) hanging by the use of a submental knot and drop invariably entailed a dislocation fracture through the arch of the axis (Figure 1) with severing of the spinal cord and instantaneous death The mechanism of the trauma in this ideal hanging injury was vigorous hyperextension combined with traction in the longitudinal direction of the spine The same injury to the cervical spine may arise in accidents especially in traffic accidents, and is often called hangman's fracture (Schneider et al 1965)

MATERIAL

The present material comprises 19 patients with bilateral fracture through the arch of the axis treated in the Odense Hospital Neurosurgical Department U and Orthopaedic Surgical Department O during the period 1962 1972. The sex ratio and age distribution are given in Figure 2. Ten were females and nine males The youngest patient was 15 and the oldest 75 years of age.

Traffic accidents are the most common cause Twelve of the patients were motor car drivers and one a cyclist The remaining six were injured by falling upon the head including one by diving into shallow water

Radiologically a fracture through the arch is often best visualized on a lateral film (Figures 3 a and 4 a) possibly supplemented by lateral tomography, whereas it is seldom seen in the anteroposterior view All the patients had bilateral fracture

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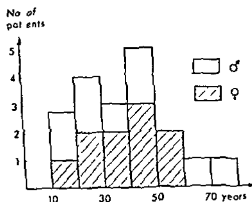


Figure 2 Sex ratio and age distribution (19 patients)

could usually be clarified with a fair degree of accuracy Three car drivers sustained an extension trauma when run into *from the rear Three patients remembered* extension trauma in connection with diving and falling accidents and after yet another fall the same mechanism was *divulged by fracture through the arch of the* sixth cervical vertebra Six patients had soft tissue injuries of the face forehead and *temporal region suggesting extension trauma Thus a total of 13 patients had* presumably been exposed to extension trauma —On the other hand there were four *patients with presumed flexion traumas viz one who remembered the trauma and* who had a soft tissue injury in the occipital region compatible with such a flexion trauma and three patients with soft tissue injuries on *the occiput and neck* One of these patients also had an avulsion fracture of the upper anterior corner of the third and fourth cervical vertebrae an injury stated to arise as a result of *hyper* flexion (Norton 1962) —Six patients were hurt by falling on the head and must have been exposed not only to extension or flexion trauma but also to vertical compression of the cervical spine Similar forces are presumably often active in traffic accidents in which the victim is flung forward injuring the head on parts of the vehicle

In two patients the mechanism of the trauma could not be elucidated in any detail

Table 1 Associated injuries (19 patients)

Injury	Patients
Soft tissue injuries to the head	12
Fracture of the skull	1
Concussion/cerebral contusion	9
Other *cervical fracture*	4
Extremity fractures	4
Multiple injuries	1

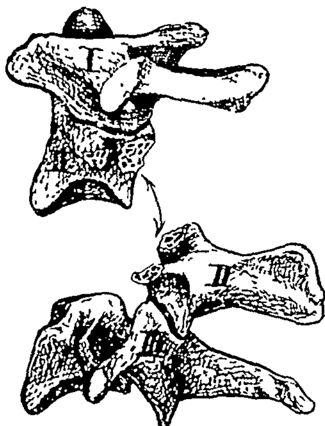


Figure 1 Hangman's fracture after hanging using submental knot (Wood Jones 1913)

through the arch of the axis most often through the weak spot of the arch at the sulcus of the spinal nerve In a few the fracture was anteriorly through the superior articular surface in others more posteriorly through the inferior articular surface or the laminae sometimes assymmetrical Fifteen patients had anterior subluxation of the body of the axis on the third cervical vertebra Two had co existing fracture of the posterior arch of the atlas (Figure 4 a) and one had bilateral fracture through the arch of the sixth cervical vertebra One had an avulsion fracture of the inferior anterior corner of the second cervical vertebra and one of the superior anterior corner of the third and fourth cervical vertebrae

Among associated injuries those affecting the head and cervical spine were by far the most common (Table 1) The site of the soft tissue injuries on the head afforded some information about the mechanism of the trauma (*vide infra*) Six patients had concussion and three cerebral contusion Two of the patients with cerebral contusion lay unconscious for 3 4 weeks with brain stem attacks both had incomplete tetraplegia but survived The third patient was lax areflexic with multiple injuries and succumbed on the sixth day after the accident without having regained consciousness Another two patients had mild signs of neurological deficits (dysaesthesia on the thumb hypaesthesia on the neck) but in the re maining 14 patients the neurological findings were normal In 7 patients the hang man's fracture was the only injury of importance All patients who were awake were complaining of pain at the back of the neck on admission

By means of the history and objective findings the mechanism of the trauma

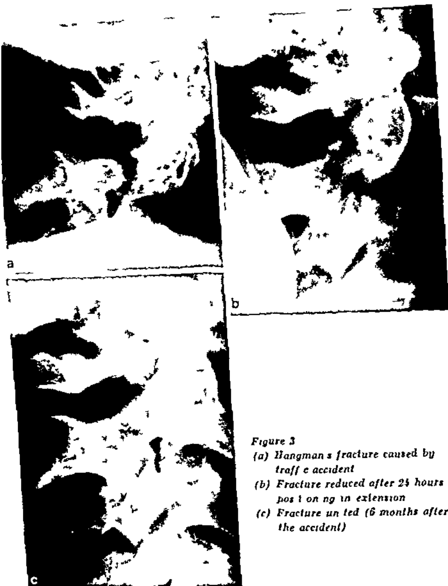


Figure 3
(a) Hangman s fracture caused by traff c accident
(b) Fracture reduced after 24 hours pos t on ng in extension
(c) Fracture un ted (6 months after the accident)

three of fatigue at the back of the neck and in the shoulders Seven had subjective limitation of movement in extension and rotation but only three had major comp laints on this account Nine were symptom free

At follow up the total range of movement in the cervical spine was measured using a goniometer (Table 3) The lower limits of normal

Table 2 Treatment (19 patients)

Posterior spinal fusion	2
Bed rest	10
Plaster cast	5
Collar	1
No treatment (died)	1

METHODS

Table 2 lists the methods of treatment In the early part of the period skeletal traction was felt to be needed, until stability had been attained in the fracture site Three of the patients who were treated by bed rest and one of those who was operated had been kept in bed with skeletal traction for from 53 to 82 days Later, the practice has been changed to positioning the patients, immediately after admission, with extended head upon a special double mattress depicted in Figure 5 a method which affords rapid and gentle reduction (Figure 3 b) and guards against secondary displacement After the primary positioning the treatment consisted in 7 cases in bed rest with extended head for about eight weeks, whereas 5 patients were treated in a Minerva jacket (Figure 6) after the fracture had been reduced during a few days' positioning in extension The importance of extension during the application of the plaster cast is illustrated by one patient whose arch fracture did not heal until the Minerva jacket was re applied during increased extension of the cervical spine This patient was in plaster for 157 days, the others from 54 to 95 days Two patients were treated by operation In one the arch fracture had united on conservative treatment, but in the course of the subsequent mobilization a rupture of the posterior ligament complex was disclosed by increasing forward dislocation of the second cervical vertebra on the third Posterior spinal fusion of the second, third, and fourth cervical vertebrae was performed The other patient had a typical hangman's fracture and was treated, a few days after the accident, by posterior spinal fusion of the first, second, and third cervical vertebrae In most cases the treatment was concluded by Camp s collar worn for up to about 6 months after the accident However, one patient was treated exclusively by Camp s collar and one patient died before any treatment could be instituted

No type of treatment caused any complications

RESULTS

The 18 surviving patients were followed up from 7 months to 9½ years after the accident One is disabled by the sequelae to cerebral contusion The other patient with brain damage has been socially and occupationally rehabilitated, although she exhibits some mental impairment and mild paresis of the limbs The other 16 patients had no neurological sequelae, but three complained of pain in the back of the neck and

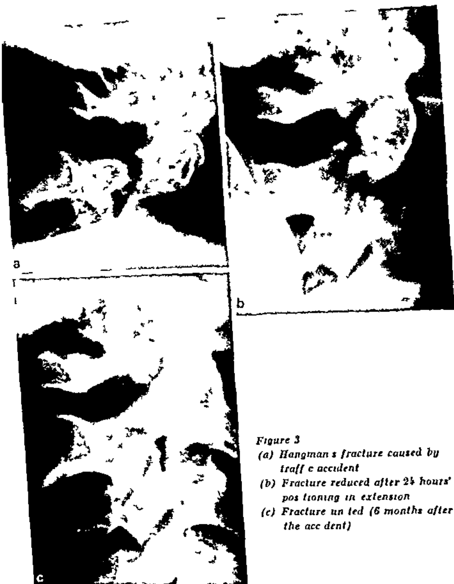


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(c) Fracture united (6 months after the accident)

three of fatigue at the back of the neck and in the shoulders Seven had subjective limitation of movement in extension and rotation but only three had major complaints on this account Nine were symptom free

At follow up the total range of movement in the cervical spine was measured using a goniometer (Table 3) The lower limits of normal

Figure 4 (a) Hangman's fracture combined with fracture of the posterior arch of the atlas due to diving into shallow water
(b) Fractures united synostosis between the second and third cervical vertebrae (4½ years after the accident)



Figure 5 Positioning in extension on a double mattress

Figure 6 Minerva jacket with the cervical spine about 30° extended



were taken to be flexion and extension 50°, rotation 80°, lateral bending 40° In assessing the range of mobility no regard was paid to age variations Out of the examined patients, five had normal mobility in all directions Flexion was reduced in only three including both patients who had been treated by posterior spinal fusion Extension was reduced in six patients Other movements were reduced in about half the patients, but only reduced rotation and extension gave rise to complaints The poorest mobility was found in a 30 year old man who had been subjected to posterior spinal fusion

The radiological end results are listed in Table 4 All the fractures united but in half the cases with a slight forward dislocation of the second cervical vertebra on the third However, the persisting subluxation was less marked than at admission There was a distinct ten

dency to spontaneous synostosis between the bodies of the second and third cervical vertebrae, especially after a long follow-up period (Figure 4 b) Both spinal fusions had healed

Table 3 Follow-up Total range of mobility in cervical spine (18 patients)

		≥ 50°	49°–30°	≤ 29°
Flexion		15	3	0
Extension		12	4	2
		≥ 80°	79°–45°	≤ 44°
Rotation	R	7	9	2
	L	7	8	3
		≥ 40°	39°–25°	≤ 24°
Lateral bending	R	8	8	2
	L	9	6	3

Table 4 Radiological end results (18 patients)

Union	18
Subluxation	9
Calcification in the ant long ligament	2
Spontaneous synostosis (CII/CIII)	5
Spinal fusion	2

The cervical injury had occupational consequences in only three cases One patient is disabled, and two have given up their previous occupation because of occipital pain Thirteen have gone back to their former work, two have retired, but are fully restored The period off work averaged 6 months (3–12 months)

There was no difference in therapeutic results between the 7 patients treated by extension positioning on a double mattress and the five patients treated in a plaster cast

DISCUSSION

Before Schneider et al 's description of 'hangman's fracture the literature on the subject was sparse Garber (1964) briefly reported his experience of eight cases, but otherwise the injury was reported only

as single cases in major clinical series of cervical fractures (Grogono 1954, Rogers 1957, Durbin 1957, Norton 1962) The largest published series (40 patients) of 'axis pedicle fractures' was reported in summary form by DeLorme (1967) In the same year Pedersen et al (1967) published nine cases Cornish (1968) found 14 patients with "traumatic spondylolisthesis of the axis' among 77 cases of cervical injuries Loisel (1971) discussed the subject in detail on the basis of four cases of his own

The majority of these injuries arise in traffic accidents, the remainder are due to falls Neurological complications are few, as the spinal canal is proximally fairly wide in relation to the spinal cord and the trauma causes further decompression (Schneider et al 1965) The mechanism of the trauma is usually pronounced hyperextension (Schneider et al 1965, Pedersen et al 1967), often combined with vertical compression (Cornish 1968, Loisel 1971) More rarely the injury is due to a flexion trauma (DeLorme 1967) Hangman's fracture combined with compression fracture anteriorly in the third cervical vertebra (Rogers 1957) must be due to a flexion compression trauma

According to Holdsworth (1963) an extension trauma to the spine may entail rupture of the anterior ligament complex (anterior and posterior longitudinal ligaments and intervertebral disc), whereas the posterior ligament complex (flaval ligaments, interspinal and supraspinal ligaments) will hold Post mortem studies after hanging using a submental knot have confirmed that the anterior ligament complex is ruptured (cit Schneider et al 1965), and the same ligamentous injuries have been found in patients with hangman's fracture (Cornish 1968) Avulsion fracture at the inferior anterior corner of the vertebral body or a fracture of the posterior arch of the atlas, spinous process or arch of other cervical vertebrae indicate extension trauma, possibly combined with compression Holdsworth (1963) stated that extension injury with preserved posterior ligament complex is stable in flexion According to the present author s experience hangman's fracture forms an exception, flexion increasing the forward dislocation of the anterior loose fragment, whereas positioning in extension will reduce and stabilize it Simultaneous injury to the posterior ligament complex, caused according to Roaf (1960) and Holdsworth (1963) by a flexion rotation trauma, entails great instability

Cautious flexion extension of the cervical spine on the waking patient under fluoroscopy affords information about the degree of instability, especially of the anterior fragment The condition of the

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Cautious flexion extension of the cervical spine on the waking patient under fluoroscopy affords information about the degree of instability, especially of the anterior fragment The condition of the

posterior ligament complex cannot be assessed until the arch fracture has united In uncomplicated cases the present author has found that in a few days the fracture may be reduced by positioning the patient with backward bent head on a double mattress Thereafter, a Minerva jacket can be applied, fixing the head in extension If other injuries or other factors render it necessary, the positioning in extension on a double mattress has to be maintained for about eight weeks Posterior spinal fusion is indicated, if union of the arch fracture is followed by secondary dislocation of the axis due to rupture of the posterior ligament complex Anterior spinal fusion, used mainly by Cornish (1968), is rational, as it fixes the loose fragment, but conservative treatment is preferable, as it is harmless and according to our experience equally effective

All patients are advised to use a neck collar for up to six months after the accident or for 3–4 months after radiological union

CONCLUSION

Bilateral fracture of the arch of the axis occurs in traffic accidents and falls due to an extension trauma, more rarely due to a flexion trauma Both may be combined with vertical compression Neurological complications are rare Rupture of ligaments and discs is an important link in the injury Treatment is by positioning in extension which leads to reduction, followed by bandaging with extended head for about eight weeks The healing tendency is good Posterior spinal fusion is rarely indicated There are few permanent complaints which consist especially in pain and fatigue at the back of the neck and in the shoulders as well as a moderate limitation of movement Spontaneous synostosis between the second and third cervical vertebrae is common after a lengthy follow-up period The great majority of patients are fully restored, also occupationally

SUMMARY

From a 10-year period 19 cases of bilateral fracture of the arch of the axis, the so-called hangman's fracture, are described In 13 cases it was caused by extension trauma, in four by a flexion trauma In two cases the mechanism of the trauma was unknown The significance of coexisting ligament and disc injury is emphasized Treatment was generally conservative, and according to recent experience it should consist

in most cases in reduction during a few days' positioning in extension on a special double mattress, followed by bandaging in a Minerva jacket for approx eight weeks with the cervical spine about 30° extended Eighteen patients who survived the injury were examined at follow up from 7 months to 9½ years after the accident There were but few permanent complaints

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From a 10 year period 19 cases of bilateral fracture of the arch of the axis, the so called hangman's fracture are described In 13 cases it was caused by extension trauma, in four by a flexion trauma In two cases the mechanism of the trauma was unknown The significance of co-existing ligament and disc injury is emphasized Treatment was generally conservative, and according to recent experience it should consist

Table 1 Survey of clinical data

Age in years	11	11	13	13	15	15	15	16	16	17	17	18	18	18	18	18	19	19	19	19	19	19	19	19	19	Total 25
Sex	F	F	F	F	M	M	F	F	M	M	F	M	F	M	F	F	M	F	M	M	M	F	F	M	M	13F 12M
Known trauma						+					+						+		+							4
Low back pain	+	+	+		+	+	+	+	+	+	+		+		+	+	+		+	+	+	+		+	+	20
Sciatica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	24
Paraesthesiae		+			+	+		+				+		+		+		+	+	+	+	+			+	13
Motor changes					+	+	+	+										+	+						+	8
Sensory changes		+			+	+		+				+	+			+	+	+	+	+		+				12
Reflex changes		+		+	+	+		+							+	+			+	+	+		+	+		12
Lasègue's sign	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+	+	23
Lumbar fixation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	24
Scoliosis				+				+	+	+	+	+			+		+	+		+	+		+			12
Abnormal gait		+			+	+		+								+	+	+	+							8

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HERNIATION OF THE LUMBAR INTERVERTEBRAL DISK IN CHILDREN AND ADOLESCENTS

SVEND ERIK BORGESEN & POUL SIGURD VANG

Accepted 22 xi 73

Lumbar-disk herniation is a rare occurrence in children and adolescents In the series described by Love (1947), Webb et al (1954), Raaf (1959) and Nashold & Hrubec (1971), 1 0–2 5 per cent of all the patients operated upon for this disease were under 20 years of age Among 1750 patients who had undergone operation for lumbar-disk herniation in our department, we found twenty-five (i e 1 4 per cent) who were under twenty years at the time of operation

Some authors (Fernstrom 1955, O'Connell 1960, Rugtveit 1966, Day 1967, Fusek 1970) have expressed the view that the signs and symptoms of lumbar-disk herniation in children and adolescents differ to a significant degree from those in adults, whereas others (Key 1950, Webb et al 1954, Epstein & Lavine 1964, Weiss & Raskind 1967, Bradford & Garcia 1969) are of the opinion that no distinct differences exist

An important aetiological factor in the causation of lumbar-disk herniation in children and adolescents is physical strain of the lumbar spine We feel, however, that other equally important factors play a substantial role in the pathogenesis of herniation of intervertebral disks A study of twenty-five children and adolescents operated upon for herniation of a lumbar disk and an analysis of similar cases reported in the literature are presented below

MATERIAL

Among 1750 patients subjected to operation for lumbar disk herniation during the period from 1962 to 1972, twenty five were within the age group eleven to nineteen years at the time of operation Of these twenty four were followed for from three months to ten years after operation The average length of the observation periods was 4 2 years

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Sensory changes		+			+	+		+				+	+			+	+	+	+	+		+				12
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Scoliosis				+				+	+	+	+	+			+		+	+		+	+		+			12
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Operative Findings

All operations were performed as a partial hemilaminectomy without spinal fusion. In four patients the herniation was free, in the others incomplete. One patient had a free herniation from the fifth lumbar disk and an incomplete herniation from the fourth lumbar disk. All herniations were localized at the interspace between the fourth and fifth lumbar vertebrae or between the fifth lumbar vertebra and the os sacrum, equally distributed on both sides. No explorations were 'negative'. The pathologist reported degenerative changes in the disk material from all the patients. The ligamentum flavum was studied in twenty-one patients: pathological changes were observed in fifteen.

RESULTS

Twenty-four patients were seen at the follow-up examination. One patient, a nineteen-year-old male, was subjected to reoperation four years after the first intervention for herniation from the fourth intervertebral space. At follow-up, he still had low-back pain, sciatica and paraesthesiae. The examination was suggestive of myelopathy, but repeat myelography did not provide any explanation. Four patients had a tendency to low-back pain after physical strain. In a few patients, sensory and reflex changes had still persisted. The remaining patients had no complaints.

ANALYSIS OF REPORTED CASES

In the literature, 134 cases of intervertebral-disk herniation in children and adolescents (with follow-ups) are reported. The results of operative treatment in 158 (including the present series) are shown in Table 3. In three cases, the result was poor. In the series of Bradford & Garcia (1969), one patient was suspected of having a new herniation at the third lumbar intervertebral space. One patient described by Weiss & Raskind (1968) had still, three years after operation, residual anterior tibial and peroneus weakness. Herniation recurred in seven cases during the observation period; successful reoperation was performed in five, ankylosing spondylitis developed in one (O'Connell 1960), and the last was our above-mentioned patient. In the remaining 145 cases, the result of the first operation was good or excellent.

Sex Incidence, Traumata

In the age group under sixteen years, 61 per cent of the surgically treated patients were females, whereas 60 per cent in the age group between sixteen and twenty were males (Table 4). This difference in

Twenty years was chosen as the upper limit because the increase in height and body weight is only slight after that age. Table 1 is a survey of the clinical data showing the age and sex distribution of the patients and the results of the pre-operative examination. Low back pain and sciatica were conspicuous complaints among the patients. Lumbar fixation and a strongly positive Lasègue's test were found in nearly all the patients. It is noteworthy that lumbar fixation and a positive Lasègue's test were the only signs present in ten patients. Motor and sensory changes were far less common.

Bed rest for a fortnight and physical therapy were given a trial in all the patients. Operation was performed even in patients without motor, sensory or reflex changes.

Table 2. Radiographic findings before operation and at follow-up examination

		Number of findings	
		Pre-operative examination	Follow-up examination
Number of patients		25	22
Flattened intervertebral space	L4/L5	8	12
	L5/S1	3	7
Decreased lumbar lordosis		18	12
Lumbar scoliosis		13	10
Osteochondrosis		1	7
Sacralization		4	4
Spondylolysis		1	3

Clinical Investigations

Standard X-ray films of the lumbar spine with the patient in a standing position showed a flattened intervertebral space in eleven patients (Table 2) before operation. A decreased lordotic angle was found in eighteen patients, while lumbar scoliosis was seen in thirteen. In four patients sacralization of the fifth lumbar vertebra was revealed, and one had a slight spondylolysis. No other structural abnormalities were observed. Pre-operatively the radiographic appearance was normal in seven cases. Conray myelography was carried out in seventeen patients, Pantopaque myelography in two. In three patients the results of myelography were false negative. Cerebrospinal fluid protein was below 40 mg/100 ml in seven patients, between 40 and 60 mg/100 ml in fourteen, and above 60 mg/100 ml in four. Routine laboratory data were non-contributory in all cases.

Twenty-two patients were studied radiographically at the follow-up examination (Table 2). Nineteen patients had a flattened intervertebral space and twelve revealed decreased lumbar lordosis. Osteochondrosis had developed in six cases. Measurements of the corneal thickness did not reveal any difference between the patients and a normal population (Krause 1972).

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In the literature 134 cases of intervertebral disk herniation in children and adolescents (with follow ups) are reported The results of opera tive treatment in 158 (including the present series) are shown in Table 3 In three cases the result was poor In the series of Bradford & Garcia (1969) one patient was suspected of having a new herniation at the third lumbar intervertebral space One patient described by Weiss & Raskind (1968) had still three years after operation, residual anterior tibial and peroneus weakness Herniation recurred in seven cases during the observation period successful reoperation was per formed in five ankylosing spondylitis developed in one (O Connell 1960) and the last was our above-mentioned patient In the remaining 148 cases the result of the first operation was good or excellent

Sex Incidence, Traumata

In the age group under sixteen years, 61 per cent of the surgically treated patients were females, whereas 60 per cent in the age group between sixteen and twenty were males (Table 4) This difference in

Table 3 Results of operative treatment of lumbar disk herniation in children and adolescents reported in the literature (present series included)

	Total number of patients	Results				
		Poor	Good	Excellent	Recurrence	Good
Wahren (1946)	1			1		
Key (1950)	4			4		
Webb et al (1954)	5		1	4		
Fernstrom (1956)	1			1		
O Connell (1960)	35		10	22	3	2
Mandell (1960)	1			1		
Epstein & Lavine (1964)	10			10		
Rugtveit (1966)	7			7		
Day (1967)	11			11		
MacGee (1968)	1			1		
Weiss & Raskind (1968)	8	1		5	2	2
Bidwell & Whittaker (1968)	1			1		
Bradford & Garcia (1969)	*27*	*1*	*9*	*16*	*1*	*1*
Fusek (1970)	19		2	17		
Verger et al (1970)	2			2		
Daschner et al (1971)	1			1		
Present series	*24*	*1*	*4*	*18*	*1*	
Total	158	3	26	122	7	5

the sex distribution is statistically significant (t-test, $P < 0.02$) In the larger series of patients in all age groups operated upon for lumbar-disk herniation, 60 per cent were males (Love 1947, O'Connell 1951, Guillaume & Janny 1953, Gurdijan et al 1961, Jochheim et al 1961) Several authors have stressed the point that traumatic lesions play an important part as an aetiological factor in the development of lumbar-disk herniation in children and adolescents Among 166 patients under the age of twenty, sixty-seven (40 per cent) were found *to have* sustained a back injury In the present series, only four patients had —as far as we know—a history of back injury O'Connell (1951), Raaf (1959), Jochheim et al (1961) and Nashold & Hrubec (1971) disclosed a history of back injury in 66–75 per cent of their cases of lumbar-disk herniation

DISCUSSION

The overall incidence of disk herniation in children and adolescents is less than 3 per cent The explanation of this relatively low figure is

Table 4 *Sex distribution related to the ages of the patients reported in the literature operated upon for lumbar disk herniation The number of patients with a history of back injury is shown (present series included)*

	Number of patients					
	Under 16 years		Over 16 years		With trauma	Total number
	Female	Male	Female	Male		
Wahren (1946)	1					1
Key (1950)	2			2		4
Webb et al (1954)	4	1			1	5
Fernström (1956)	1					1
O Connell (1960)	9	7	7	15	19	38
Mandell (1960)	1					1
Epstein & Lavine (1964)	1		4	5	7	10
Rugtveit (1966)	1	3	2	1	2	7
Day (1967)		4	4	6	3	11
MacGee (1968)		1			1	1
Weiss (1968)	1	1	1	5	[illegible]	8
Bidwell (1968)	1					1
Bradford & Garcia (1969)	5	6	6	13	14	30
Fusch (1970)	6	1	10	3	10	20
Verger (1970)	2					2
Daschner (1971)	1				1	1
Present series	5	2	8	10	4	25
Total	41	26	39	60	67	166

threefold most surgeons are reluctant to resort to operation in this age group a definite diagnosis is only rarely established and the precipitating factors in the pathogenesis of lumbar disk herniation change both quantitatively and qualitatively after the age of twenty years

The clinical picture of disk herniation in children and adolescents differs to some extent from that seen in older age groups Pain is the most common symptom while lumbar fixation and a positive Lasègue s test are the most frequent objective findings Spangfort (1972) has shown that when Lasegue s sign is correlated to the age at operation, the incidence of the sign decreases constantly with age Other neurological abnormalities are less frequent This discrepancy between disk herniation in teenagers and adults may be attributed to greater mobility of the young spine, which thus facilitates the relief of pressure on the nerve root (O Connell 1960, Epstein & Lavine 1964 Day 1967, Bradford & Garcia 1969)

Seven of the twenty-five patients in this series showed no radiographic changes in plain X-ray films of the spine. Thirteen had changes indicative of disk disease. O'Connell (1960) reported that only one half of his series of thirty-eight patients had radiological changes indicating the presence of a disk protrusion. Day (1967) and Bradford & Garcia (1969) also emphasized that only a small number of their patients revealed changes in plain X-ray films of the spine. Accordingly, myelography may be inevitable in establishing the diagnosis and the level of the disk herniation.

The results of surgical treatment of lumbar-disk herniation in children and adolescents are good. While the results of surgery for disk herniation in all age groups are reported to be 'good' or 'excellent' in 75–90 per cent in most larger surveys (Love 1947, Giullaume & Janny 1953, O'Connell 1951, Gurdijan et al. 1961, Nashold & Hrubec 1971), 'good' and 'excellent' results were achieved in 98 per cent of the patients (153 out of 158) under twenty years of age with surgically treated lumbar-disk herniation. One of the reasons for the good surgical results may be that the patients are still at an age at which they can learn to 'live with their back', and guard themselves against further physical strain or heavy work. The indications for operation differ from those in adults. We find that a strongly positive Laségue's test, lumbar fixation and a guarding scoliosis justify operation, even if there are only minor complaints of pain. Conservative treatment should be given a trial, but we are under the impression that most of these patients do not respond too well to this sort of treatment, and that they do, in fact, obtain better relief from their symptoms by surgical intervention.

In the age group under sixteen years, there is a significant preponderance of females among patients with surgically confirmed lumbar-disk herniation, whereas the sex distribution in the group over sixteen does not to any significant degree differ from that of adult patients. In an attempt to explain this reversal in the sex incidence, O'Connell (1960) considered the difference in the annual increments in weight and height in the two sexes In girls, the most rapid increases in both weight and height occur from eleven to fifteen years of age, while the corresponding period extends from thirteen to seventeen years in boys (Heminder 1970). As further stated by O'Connell, "it may well be that stresses developed in the low back during the period of rapid growth may be of significance in the development of lumbar disk protrusion".

In the present series of twenty nine patients, the pathologist found degenerative changes in the disk material from all the patients. Bradford & Garcia (1969) observed such changes only in eight of their thirty patients. Key (1950) and O'Connell (1960) reported that the disk material as observed at operation appeared clearer and more watery than is usually seen in adults.

The incidence of an antecedent trauma in children and adolescents with surgically confirmed lumbar-disk herniation does not differ to a significant degree from that in adults. It is also reasonable to emphasize that a trauma as the only cause of herniation from a previously normal disk is unlikely. We therefore suggest that degeneration of the disk is the primary cause, and that a trauma is only a precipitating factor in the development of lumbar-disk herniations.

In this connection it may be of interest to mention that other affections suggestive of 'connective-tissue disease' did not occur with a strikingly high frequency among our patients, nor did measurements of the corneal thickness at the follow-up examinations reveal any evidence of mesenchymal changes in the patients. It is possible, however, that further investigations including histochemical analysis of mesenchymal structures may provide an explanation of the question why disk disease develops in some patients, while it does not occur in others under the same external conditions.

SUMMARY

A consecutive series of twenty five patients aged from eleven to nineteen years with surgically treated lumbar disk herniations is reported. An analysis is presented of the results in 158 follow-up cases on record (including our own). It is emphasized that a 'good' or 'excellent' result was obtained in 98 per cent, which is much better than the figures usually reported in follow ups of operative treatment of lumbar disk herniations in all age groups.

The clinical picture of lumbar disk herniation in children and adolescents differs from that seen in adults. As in adults, pain is a conspicuous symptom whereas complaints of sensory or motor disturbances are less frequent in the young. Lumbar fixation and a strongly positive Lasegue's test are the most common signs, whereas other neurological manifestations of nerve root compression are less common in children and adolescents. The radiographic appearance of the spine in plain X ray films was found to be indicative of disk disease only in

about one half of the patients For this reason, myelography may be necessary in establishing the diagnosis and the level of herniation

The aetiological factors in the development of lumbar disk herniation are discussed It is emphasized that degeneration of the disk is most likely to be the primary cause, whereas a traumatic lesion is thought to be only a precipitating factor

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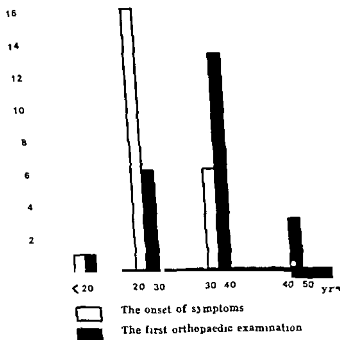


Figure 1 Age distribution of 23 patients with pelvic relaxation

MATERIAL AND METHODS

During the period 1951–1971 23 patients have been treated in Martina Hansens Hospital with the diagnosis of pelvic relaxation, 17 as inpatients and 6 as out patients

The records were reviewed with particular attention being paid to positive statements of any back pain or gynaecological disease before the first pregnancy and possible information pointing towards psychoneurotic behaviour All patients with a doubtful diagnosis of pelvic relaxation were excluded from the material

The age distribution of the patients at the onset of symptoms and at the first examination at the hospital is given in Figure 1

The majority (19 out of 23 women) were referred to our department from the obstetrician with a strong suspicion of their having pelvic relaxation some of them with severe symptoms Ten patients came for orthopaedic treatment within a time period of 3 months from the preceding delivery, 4 patients came between 6 and 12 months and the remaining 9 between 12 and 18 months after delivery

Table 1 presents the first appearance of symptoms in relation to the number of pregnancies or times in labour The symptoms showed a tendency to begin from the 28th to the 30th week of the pregnancy and in the course of 48 hours after the parturition In 16 cases there were unequivocal symptoms of relapses of pelvic relaxation during altogether 33 later pregnancies The recidivations were noticed at

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Martina Hansens Hospital, Sandvika, Norway

PELVIC GIRDLE RELAXATION FROM AN ORTHOPAEDIC POINT OF VIEW

Rolf Hagen

Accepted 15 x 73

The term pelvic relaxation is related to certain conditions during and after pregnancy, and implies that the joints and ligaments have a reduced ability to accomplish their function as supporting structures There is widespread acceptance that the relaxation is due to a specific high-molecular hormone, relaxin, which is present in the serum of various pregnant mammals including women Its chemical composition is not yet defined (Cohen 1963, Steinetz 1963)

The firmness of the pubic symphysis and the tension of the capsule and ligaments of the sacroiliac joints are decreased in pelvic relaxation Consequently, a sliding movement and an instability may occur in the pelvic joints

Morphological changes of these joints during pregnancy appear as a physiological condition without clinical symptoms Occasionally, these changes dispose to pain and in this way become pathologic Meanwhile, the transition between physiological and pathological relaxation is rather indistinct

The communications in the obstetrical literature about pathological relaxation vary regarding the incidence of this condition Berezin (1954) reports a frequency of 0 4 per cent in pregnancy and 0 2 0 3 per cent during and after parturition Skajaa (1929), Walde (1962) and Genell (1949) have published an incidence of 16 per cent, 0 5 3 per cent and 1 per cent, respectively, in their materials of pregnant women

Little has so far been reported about this condition from an orthopaedic point of view For this reason the following study has been carried out with special emphasis on the morphological, biomechanical, clinical and therapeutic problems The hormonal aspects of the disorder will not be discussed in this paper

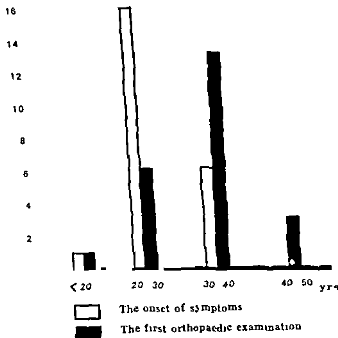


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a constantly earlier time from pregnancy to pregnancy, and also with an increasing intensity. The remaining 7 women have passed through only one pregnancy up to the time of follow up.

In 6 cases a sterilization was performed in the post partum period and an artificial abortion was provoked 4 times in 3 women. A family disposition was encountered in only 2 cases.

Table 1. First appearance of symptoms of pelvic relaxation in relation to pregnancy and labour

During pregnancy	19	1st	10	week 16–19	2
		2nd	7	week 20–23	3
		3rd	2	week 24–27	2
				week 28–31	3
				week 32–35	7
				week 36–40	2
During 1st labour	1				
After 1st labour	3				

Table 2. The treatment of 23 women with pelvic relaxation

Conservative		15
Operative		
Arthrodesis of both s. i. joints	4	8
Arthrodesis of both s. i. joints + symphyseodesis	2	
Symphyseodesis	2	

Treatment

This is listed in Table 2. Active exercises, bed rest with a broad pelvic sling, crutches and a sacroiliac belt or a firm supporting corset constitute the most important conservative measures in this material. The conservative treatment lasted on an average for 4 months.

Arthrodesis of the sacroiliac joints was done by Smith Petersen's method. By chiselling out a rectangular bone piece 4×2×3 cm in size the ear shaped joint was completely opened. After removal of the cartilage from the sacral side of the joint and also from the bone block the latter was replaced and countersunk to come into close contact with the cancellous bone of the sacrum. In addition bone chips from the iliac bone were packed into the interspaces surrounding the block to promote the osteogenesis.

The postoperative regimen consisted of vigorous isometric contractions of the gluteal muscles from the second day. The patient was permitted to sit in a wheel chair or walk carefully with crutches swinging through and weightbearing on both legs simultaneously from the seventh postoperative day. A 4 point gait was started after 8–10 weeks and the crutches were discarded about 14 weeks postoperatively.

The symphysis was approached through a transverse incision, the fibrocartilage *resected into bleeding* bone and a suitable bone graft from the iliac crest fitted into the defect, supplemented with bone chips on the posterior side Then usually immobilisation was carried out with 1–2 staples or plates The aftertreatment was as described above apart from bed rest for 2–3 weeks

There were no serious postoperative complications *Histological examination of* the cartilage of the pelvic joints was made in only 2 cases

Follow-up examination

All the patients were examined clinically and 21 roentgenologically *from 1 to 21* years after the final ambulatory treatment or their discharge from the hospital, the average observation time being 6 years

Both the original and follow up roentgenograms were studied with special regard to the separation and vertical mobility of the symphysis, *a possible sclerosis and* irregularity of the pubic bones and any signs of a widening or para articular sclerosis of the sacroiliac joint

Measurement was made of the width of the symphysis at the narrowest space and *the vertical shift made up of the total of the differences in levels between the* upper borders of the pubic bones with the patient standing on the right and left leg alternately The X rays should be taken with a 8 cm wooden block under the foot and the unloaded leg hanging freely An ordinary A P view of the sacroiliac joint was usually supplemented by stereoscopic and tangential projections

Table 3 Clinical symptoms and signs of relaxation in 23 patients

Pain and tenderness of the s i joint (one or both)	23
Pain and tenderness of the symphysis	23
Pain and tenderness of the adductor muscle	12
Difficulties in walking	14
Positive Trendelenburg s sign	10

RESULTS

Clinical follow-up

Initially, the main symptoms of pelvic relaxation were spontaneous pain and tenderness by direct or indirect pressure localized to the pelvic joints as indicated in Table 3 About one half of the patients com plained of pain and tenderness in the inguinal region and in the medial part of the thigh, which was probably due to increased strain upon the adductor muscles because of the pelvic instability Characteristically the pain was provoked by any active movement, either by moving the legs, ascending or descending stairs, changing position in bed or lifting heavy objects In cases of severe involvement, the patient

moved in a hesitating manner with a waddling, goose-like gait and short steps and kept the lower extremities tight together and a little internally rotated

A very important clinical observation in 10 cases was a bilateral positive Trendelenburg's sign, and during this examination 3 patients experienced a snapping sound in the symphysis while a vertical symphysial movement could be demonstrated by palpation

Table 4 Roentgenological findings of pelvic relaxation in 21 patients at the time of the first orthopaedic examination

Symphysial width	2–5 mm	19
	> 10 mm	2
Symphysial shift	< 5 mm	18
	> 5 mm	3
Para artic sclerosis and widening of s i joints		3
Osteochondral changes of the symphysis		1

Roentgenological follow-up

The results are enumerated in Table 4 Previous investigations have shown that all pregnancies normally are connected with an increased width and shift of the symphysis (Farbrot 1952, Heyman & Lundqvist



Figure 2 Female aged 52 years symphyseodesis and arthrodesis of sacroiliac joints in 1951 and reoperations of all joints 2 years later because of non union Roentgenological ankylosis and fair result at follow-up



Figure 3 Female aged 47 years symphyseodesis with autologous bone block in 1962 nine months after third delivery Solid ankylosis and good result



Figure 4 Female aged 44 years symphyseodesis in 1964 with bone block and 1 staple one year after fourth delivery Good result

1932 Roberts 1934 Thorp & Fray 1938) In the present material a separation of more than 10 mm and a vertical mobility of more than 5 mm are listed as pathologic These changes together with sclerosis and widening of the sacroiliac joints were able to confirm the diagnosis based on clinical judgement in only 4 patients In other words the X rays are mostly normal in pelvic relaxation at the time of the first orthopaedic examination



Figure 5 Female, aged 43 years, a 6 cm width at symphysis pubis 4 days after fifth delivery in 1967 Conservative treatment

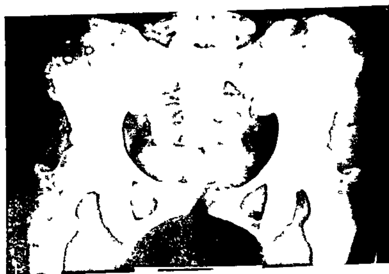


Figure 6 1½ cm distance between the pubic bones at follow-up Disabling pain and pelvic instability Poor result

One patient revealed non-union of both sacroiliac joints and the symphysis 2 years after the operations and was reoperated in all three pelvic joints with a roentgenologically successful result (Figure 2) Six of the remaining 7 operated patients showed signs of ankylosis of the joints (Figures 3 and 4) As regards the sacroiliac joints, it should be emphasized that the transformation and incorporation of the bone block continues for a rather long time The process of union may be



Figure 7 Female aged 40 years osteoarthritic changes of the symphysis and a vertical mobility of 7 mm Poor result after conservative treatment

followed roentgenologically for 10 years until the stage of solid fusion is reached

On follow up, the state of the patients was classified according to the following criteria

Good—17 patients

Symptom free or slight pain during the first days of menstruation, pelvic stability, roentgenological ankylosis of pelvic joints, independent of sacroiliac belt or corset, normal working ability

Fair—3 patients

Pain on heavy housework and on walking long distances, pelvic stability solid ankylosis periodically dependent on external pelvic support and/or physiotherapy

Poor—3 patients

Pain on light effort and on walking short distances, pelvic instability, non union or doubtful ankylosis, disability insurance owing to previous relaxation

Two of the patients with a poor final result have been conservatively treated A 43 year old woman with marked clinical and roentgenological symptoms was offered an arthrodesis of the pelvic joints, but refused operative treatment (Figures 5 and 6) A 40 year old patient revealed, as well, positive roentgenological signs, and a symphyseodesis is planned at a later time because of pain and pelvic instability (Figure 7) Lastly, a 45 year-old woman presented non union of both sacroiliac

joints. A bilateral rearthrodesis seems not to be indicated because of moderate complaints in spite of the operative failure

One of the 3 women belonging to the group "fair" has had 4 operations on the pelvic joints (Figure 2) The remaining 2 patients have only been conservatively treated

DISCUSSION

After post-mortem examinations of the symphysis some authors (Eymer & Lang 1929, Haslhofer 1930) have drawn attention to the appearance of irregular fissures in the fibrocartilage and to alterations of the osteochondral junction These changes are similar to an osteoarthritic process, as indicated roentgenologically in one of our patients (Figure 7) The subchondral bone tissue is further found to be partially penetrated with subsequent open communication between the bone marrow and the cartilage This facilitates an invasion of the cartilage from the bone marrow with its abundance of cells and capillaries Yet, this seems to be a rather rare occurrence and of a definitely pathologic nature

The symphysis is a synchondrosis with fibrocartilaginous union between the pubic bones while the sacroiliac joints constitute an amphiarthrosis The pelvic joints are reinforced by strong ligaments which permit only slight motion The articular surfaces of the sacroiliac joint lie farther apart anteriorly than posteriorly, and therefore the sacral bone tends to displace forwards and downwards into the pelvis during weightbearing The interosseous and posterior sacroiliac ligaments counteract this tendency by becoming taut and forcing the ilia more closely together

The efficiency of this locking mechanism is impaired in some women in whom the sacroiliac joint lies in the sagittal rather than in the more oblique plane Besides, the articular surfaces are more even in females than in males and permit a slightly greater range of motion during physiologic as well as pathologic conditions Thus, anatomical variations of the female sacroiliac joint very likely play a certain role in pelvic relaxation

The analysis of this material gave no evidence for the view that women with a "male looking' pelvis or coxa valga may show a predisposition to pelvic relaxation, as indicated in the literature (Seyss 1964) All the patients revealed a "female looking pelvis as judged by the roentgenograms and a neck-shaft angle within normal limits



Figure 8 Female aged 40 years arthrodesis of all pelvic joints after eighth delivery Preoperative widening and para articular sclerosis of sacroiliac joints

Biomechanics

The forces acting on the pelvic joints should also be taken into consideration Pauwels (1965) has calculated the relative magnitude and direction of the forces which affect the sacroiliac joints and the symphysis in one and two-leg support The forces were calculated for the plane of the pelvic girdle as well as for the plane perpendicular to it

According to these calculations the resultant forces will cause a preponderance of tensile stress in the symphysis during weightbearing on both legs even if a certain compressive component is acting in the sacroiliac joints to maintain equilibrium with compressive forces in the proximal and tensile in the distal portion During one-leg support in gait strong shearing forces are acting on the symphysis simultaneously in two opposite vertical directions

It is supposed that the histological structure of the symphysis consists chiefly of fibres which slope in all directions between the two pubic ends to equalize the shearing forces and horizontal fibres to eliminate the tensile stress Besides this the cartilage of the joints tend to resist and take up the compressive stress

Hormonal influence (Manning et al 1965) and increased stress during pregnancy and labour may be responsible for possible histochemical changes of the cartilage of the pelvic joints Oestrogen and relaxin cause depolymerization of hyaluronic acid (Hall 1956) and compressive shearing and tensile forces constitute a chronic trauma increasing the concentration of hyaluronidase or an enzyme akin to it This interferes with the humoral conditions needed for pelvic stability and very likely also plays a certain role as a pathogenetic factor in pelvic relaxation

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ritated by a pelvic instability giving rise to sciatica Thus, the clinical pictures may be very similar

Occasionally, the x-rays reveal a para articular sclerosis of the sacroiliac joint in the medial and distal part of the ilium, as in 3 of our patients (Figure 8) Bársony & Polgár (1928) directed attention to these roentgenological changes and gave them the term osteitis condensans ilii Later, several authors have reported this condition (Matsumaru 1966 Rendich & Shapiro 1936, Rojkó & Farkas 1960, Shipp & Haggart 1950)

This densifying reaction of the iliac bone seems to appear as a late manifestation in some women who have borne several children The compressive forces in the distal part of the joint together with anatomical variants should be taken into consideration in this connection The sclerosis as such, apparently produces no clinical symptoms However, it should also be remembered that Mb Bechterew, Paget s disease tuberculosis and primary osteoarthritis may give rise to similar roentgenological changes

Therapy and prognosis

In most cases the symptoms disappear either spontaneously or with appropriate conservative measures during the first weeks after delivery and rarely last more than 1 months

The material seems to indicate that the occurrence of symptoms in younger age groups, first time relaxation and early treatment after delivery constitute favourable prognostic factors Besides, the patients usually made a quicker recovery from their first relaxation than after possible relapses It is also emphasized that our 3 patients with the first appearance of relaxation after delivery recovered after a relatively short period of conservative treatment

The symphysial width and vertical mobility are not the decisive factors in the development and degree of involvement of pelvic relaxation However a symphysial width of more than 10 mm and a shift more than 5 mm combined with widening and para articular sclerosis of the sacroiliac joints have a tendency to cause a delayed convalescence The prognosis is more doubtful in such cases treated conservatively and an operation is recommended

Occasionally, the convalescence may also be delayed in some cases with marked back pains and normal x rays The symptoms are rather diffuse in these chronic cases, i e complaints lasting for more than 6 months after delivery The clinical picture appears to be rather com-

Diagnosis

As regards the clinical problems, it is important to realize that the diagnosis may be difficult, especially if too much time has elapsed since the delivery. Obviously, it would be a great advantage if the orthopaedic surgeon could be consulted as soon as possible in the post-partum period to get an early and personal impression of the severity of the condition and to rule out possible diagnostic errors

The review of the present material has made clear that several diseases may contribute to diagnostic difficulties Dorsalgia from insufficiency of the back muscles, leg length discrepancy or a psychosomatic mechanism may easily be incorrectly diagnosed as pelvic relaxation

Another source of diagnostic error seems to be static lumbosacral pain because of increased strain upon the back muscles The centre of gravity during pregnancy is influenced by increasing weight and abdominal distension The effect of the stretched abdominal muscles is decreased from a biomechanical point of view Usually, the back pain disappears during the puerperium and bears no relation to pelvic relaxation

Degenerative diseases, spondylolisthesis and benign bone tumours of the lumbar spine and dysplasia of the hip joint have also proved to be actually mistaken diagnoses in our material Vertebral osteoporosis in the puerperium, spondylitis and an asymmetric transitional vertebra seem to be less frequent causes of mistakes

Special interest is attached to the question as to whether there is any pathogenetic relation between pelvic relaxation and disc herniation There is indeed a certain structural and functional similarity between the pelvic joints and the intervertebral discs It is reasonable to suppose that the discs also will be exposed to hormonal influence and increased biomechanical strain during pregnancy

Five of our 23 patients have been treated for disc herniation, the symptoms appearing in connection with pregnancy and delivery Walde (1962) reports that 13 out of 137 patients with relaxation were treated for disc herniation in an obstetrical material Erici & Sjövall (1963) maintain that lumbo-ischialgia is rather infrequent in pregnant women From a diagnostic point of view it is important to realize that disc changes may ensue during pregnancy and closely resemble pelvic relaxation In addition, the 4th and 5th lumbar roots have a rather close anatomical relationship to the sacroiliac joint and may be ir-

ritated by a pelvic instability giving rise to sciatica Thus, the clinical pictures may be very similar

Occasionally, the x rays reveal a para articular sclerosis of the sacroiliac joint in the medial and distal part of the ilium, as in 3 of our patients (Figure 8) Barsony & Polgár (1928) directed attention to these roentgenological changes and gave them the term osteitis condensans ilii Later, several authors have reported this condition (Matsumaru 1966 Rendich & Shapiro 1936, Rojko & Farkas 1960, Shipp & Haggart 1950)

This densifying reaction of the iliac bone seems to appear as a late manifestation in some women who have borne several children The compressive forces in the distal part of the joint together with anatomical variants should be taken into consideration in this connection The scle[illegible] as such apparently produces no clinical symptoms However [illegible] disease [illegible] roentgenological changes

Therapy and prognosis

In most cases the symptoms disappear either spontaneously or with appropriate conservative measures during the first weeks after delivery and rarely last more than 4 months

The material seems to indicate that the occurrence of symptoms in younger age groups, first time relaxation and early treatment after delivery constitute favourable prognostic factors Besides, the patients usually made a quicker recovery from their first relaxation than after possible relapses It is also emphasized that our 3 patients with the first *appearance of relaxation* after delivery recovered after a relatively short period of conservative treatment

The symphysial width and vertical mobility are not the decisive factors in the development and degree of involvement of pelvic relaxation However, a symphysial width of more than 10 mm and a shift more than 5 mm combined with widening and para-articular sclerosis of the sacroiliac joints have a tendency to cause a delayed convalescence The prognosis is more doubtful in such cases treated conservatively and an operation is recommended

Occasionally, the convalescence may also be delayed in some cases with marked back pains and normal x-rays The symptoms are rather diffuse in these chronic cases, i e complaints lasting for more than 6 months after delivery The clinical picture appears to be rather com-

Diagnosis

As regards the clinical problems, it is important to realize that the diagnosis may be difficult, especially if too much time has elapsed since the delivery. Obviously, it would be a great advantage if the orthopaedic surgeon could be consulted as soon as possible in the post-partum period to get an early and personal impression of the severity of the condition and to rule out possible diagnostic errors.

The review of the present material has made clear that several diseases may contribute to diagnostic difficulties. Dorsalgia from insufficiency of the back muscles, leg length discrepancy or a psychosomatic mechanism may easily be incorrectly diagnosed as pelvic relaxation.

Another source of diagnostic error seems to be static lumbosacral pain because of increased strain upon the back muscles. The centre of gravity during pregnancy is influenced by increasing weight and abdominal distension. The effect of the stretched abdominal muscles is decreased from a biomechanical point of view. Usually, the back pain disappears during the puerperium and bears no relation to pelvic relaxation.

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plex, the original relaxation symptoms contributing only one component. Static disturbances, insufficiency of the back muscles and psychoneurotic features are prominent. The prognosis is also doubtful in such cases, and a surgical intervention is not recommended.

From an anatomical point of view it is probable that the symphysial shift is due mainly to increased mobility of the sacroiliac joints. Therefore, in most cases where an operative treatment is indicated, it is reasonable to arthrodese the sacroiliac joints first as a one stage procedure. Persistent pain and instability of the symphysis requires a symphyseodesis.

A 22-year-old patient in the material with a bilateral arthrodesis of the sacroiliac joints has gone through one delivery without complications. However, the remaining 7 women were operated upon at a mean age of 35 years after the cessation of their childbearing. At any rate, it is recommended that an arthrodesis of all three pelvic joints be postponed until that time.

SUMMARY

The morphological, biomechanical, clinical and therapeutic problems of pelvic relaxation from an orthopaedic point of view are discussed in this paper.

A total of 23 patients have been treated in Martina Hansens Hospital during the period 1951–1971, 15 conservatively and 8 operatively. At follow-up, 17 patients belonged to the group "good", 3 were judged as "fair" and 3 as "poor".

Conservative treatment gives a successful result in the majority of cases. With lasting symptoms from relaxed sacroiliac joints a bilateral arthrodesis as a first stage procedure is recommended. Persistent instability and pains of the pubic symphysis require a symphyseodesis.

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MATERIAL AND METHODS

The series comprises 70 patients with medial fracture of the neck of the femur treated at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki and at the Central Hospital Vaasa In all cases the injured femoral head was removed and replaced by an endoprosthesis Sixty one femoral heads were removed in connection with a primary prosthetic arthroplasty while 9 heads were excised on account of unsatisfactory healing several months after primary nailing of the fracture

The patients received 250 mg oxytetracycline (OTC) intramuscularly twice a day for two days before the operation The femoral head and the base of the femoral neck lateral to the fracture were taken for further examination The samples were bisected in the frontal plane one half of the sample was fixed in neutral 10 per cent formalin for histological examination and the other half in absolute alcohol for fluorescence microscopy Paraffin embedded sections were stained with Weigert van Gieson's haematoxylin and methylmethacrylate embedded specimens were ground to a thickness of 100 μ prior to microscopic examination

RESULTS

On the basis of the histological pattern and the occurrence of OTC uptake in the femoral head and femoral neck the material was classified into three groups as follows

1) *No uptake of fluorescent material* In 47 femoral heads no OTC-uptake could be demonstrated (Figure 1) All these specimens were obtained in cases of recent fracture However fluorescence was regularly observed in samples taken from the base of the femoral neck

2) *Subchondral uptake of fluorescent material* In 14 femoral heads fluorescence was seen subchondrally at different sites around the circumference of the femoral head The fluorescence occurred as sickle shaped thin bands immediately under the articular cartilage (Figure 2)

3) *Irregular uptake of fluorescent material in inveterate fractures* In 9 old inveterate fractures nailed before endoprosthetic replacement was performed fluorescence was seen in the bone trabeculae of the femoral head (Figure 3) The fluorescence predominantly occurred along the previous nail track and in the callus tissue around the femoral neck

OTC uptake was irregular and corresponded in the histological sections to the granulation tissue and new bone invading these areas In the femoral heads signs of creeping substitution of necrotic bone areas were observed as the process of repair advanced from the femoral neck towards the femoral head

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DEVITALIZATION OF THE FEMORAL HEAD AFTER MEDIAL FRACTURE OF THE FEMORAL NECK

P Rokkanen & P Slätis

Accepted 3 xii 73

Nutrition of the femoral head is impaired after medial fracture of the neck of the femur The blood supply to the femoral head via the cancellous bone is always affected by the fracture itself, in severely displaced fractures damage to the epiphyseal arteries in the joint capsule further reduces the circulation in the femoral head The blood vessels of the ligamentum teres are of minor importance in the nutrition of the femoral head (Sevitt & Thompson 1965, Wertheimer & Lopes 1971) As a result of the altered nutritive conditions, bone necrosis can be observed histologically in more than ⅔ of patients with medial femoral neck fractures (Phemister 1934, Sevitt 1964, Bohr & Larsen 1965, Catto 1965 a, Sevitt & Thompson 1965)

Assessment of the viability of the femoral head after medial fracture of the femoral neck is clinically difficult (Hulth 1965) Attempts to evaluate the blood supply of the femoral head have been made pre- and peroperatively by arteriography (e g Rook 1953, Hipp 1962, Mussbichler 1970), by venography (e g Hulth 1956, Hulth & Johansson 1962, Eberle 1971) and isotope techniques (e g Tucker 1950, Boyd et al 1955, Eegholm 1970, McNeur 1970) Interpretation of the results is difficult, however, and none of these methods has gained any wide clinical acceptance

In this study the viability of the femoral head was examined by the tetracycline labelling method Tetracyclines are deposited in the growth areas of living bone and in newly formed bone in callus tissue formed during fracture repair Tetracycline uptake in the bone can be traced by fluorescence microscopy Experimental studies in the rabbit have shown that an avascular femoral head does not display tetracycline fluorescence (Rokkanen et al 1965)

MATERIAL AND METHODS

The series comprises 70 patients with medial fracture of the neck of the femur treated at the Department of Orthopaedics and Traumatology, University Central Hospital, Helsinki and at the Central Hospital, Vaasa. In all cases the injured femoral head was removed and replaced by an endoprosthesis. Sixty one femoral heads were removed in connection with a primary prosthetic arthroplasty, while 9 heads were excised on account of unsatisfactory healing several months after primary nailing of the fracture.

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1) *No uptake of fluorescent material.* In 47 femoral heads no OTC uptake could be demonstrated (Figure 1). All these specimens were obtained in cases of recent fracture. However, fluorescence was regularly observed in samples taken from the base of the femoral neck.

2) *Subchondral uptake of fluorescent material.* In 14 femoral heads fluorescence was seen subchondrally at different sites around the circumference of the femoral head. The fluorescence occurred as sickle shaped, thin bands immediately under the articular cartilage (Figure 2).

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OTC uptake was irregular and corresponded in the histological sections to the granulation tissue and new bone invading these areas. In the femoral heads signs of creeping substitution of necrotic bone areas were observed as the process of repair advanced from the femoral neck towards the femoral head.





Figure 1 a Fluorescence micrograph of the femoral head in a 69 year old woman The femoral head was extirpated 17 days after fracture of the neck of the femur in connection with the application of an endoprosthesis No fluorescence is seen in the trabeculae

Figure 1 b Fluorescence is observed in the femoral neck distal to the fracture



Figure 2 Fluorescence micrograph of the subchondral part of the femoral head after recent fracture of the neck of the femur in a 78 year old woman Fluorescence is seen subchondrally



Figure 3 Fluorescence micrograph of the femoral head in a 68 year old woman The femoral head was extirpated 2 years after a fracture of the neck of the femur which was nailed 11 days after injury Fluorescence is seen in the trabeculae as a sign of regenerative new bone formation

DISCUSSION AND CONCLUSIONS

It emerges from this study that after a recent medial fracture of the femoral neck, OTC uptake in the femoral head does not occur or is present only in the subchondral area, whereas OTC fluorescence is abundant at the base of the femoral neck, lateral to and in close proximity to the fracture This indicates that the nutrition of the cancellous bone in the femoral head is markedly impaired, and that subsequent ischaemic changes in the femoral head are apt to occur in all cases of medial fracture of the neck of the femur The results corroborate previous reports of a high incidence of bone necrosis after medial fracture of the femoral neck (Sevitt 1964, Bohr & Larsen 1965), but they also show that after this type of trauma nutrition of the femoral head is more constantly and severely impaired than has previously been assumed

Reduced nutrition of the femoral head affects the healing conditions of these fractures, and the choice of treatment is an intricate problem to the clinician Repair of a medial fracture of the femoral neck largely depends on a close and undisturbed contact between the cancellous fragments

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Figure 2 Fluorescence micrograph of the subchondral part of the femoral head after recent fracture of the neck of the femur in a 78 year old woman Fluorescence is seen subchondrally

cellous bone can be nourished by the synovial fluid through the articular cartilage However nutrition by this route is limited to a narrow area of cancellous bone and cannot prevent aseptic necrosis of the femoral head after medial fracture of the femoral neck

It may be concluded that after medial fracture of the femoral neck the nutrition of the femoral head regularly deteriorates so much that healing conditions become extremely unfavourable From the clinician s point of view time consuming and often unspecific determinations of the viability of the femoral head may not seem to be indicated under these circumstances The present findings constitute evidence in favour of the use of primary replacement arthroplasty in the treatment of medial fractures of the neck of the femur

SUMMARY

Seventy patients with fractures of the neck of the femur received oxytetracycline preoperatively for fluorescence microscopy of the bone Sixty one patients had a recent fracture nine had inveterate non united fractures of the femoral neck In all cases the femoral head was replaced by an endoprosthesis Fluorescence microscopy of the femoral head revealed no fluorescence centrally in the femoral head after a recent fracture of the neck of the femur whereas fluorescence could regularly be seen at the base of the femoral neck In 14 cases fluorescence was observed subchondrally in the femoral head indicating scanty nutrition of the juxtachondral cancellous bone through the articular cartilage Irregular fluorescence was observed in the trabeculae of the femoral head in inveterate cases as a sign of bone regeneration

The results indicate that severe nutritional disturbances regularly occur in the femoral head after medial fracture of the neck of the femur and speak in favour of the application of an endoprosthesis in the treatment of severely displaced fractures

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The process of repair advances from the vascularized femoral neck towards the poorly vascularized or avascular femoral head and ultimately leads to healing of the fracture as well as revascularization of the femoral head Poor contact between the fragments is detrimental to fracture healing and often results in a progressive shortening of the femoral neck due to resorption of bone at the borderline between the advancing regenerating tissue and the avascular cancellous bone A necrotic femoral head *is slowly replaced by regenerating tissue,* and as new bone is laid down on the old trabecular lattice-work, the radiographic density of the femoral head gradually increases Revascularization of the femoral head causes softening, often leading to flattening Restoration *of the cancellous blood flow is essential to the process of* repair Consolidation of the fracture and maintained viability of the femoral head can be expected only when the fragments are well reduced and rigidly fixed by nailing (Garden 1971) or impacted (Bentley 1968)

The high incidence of nutritive disturbances of the femoral head after medial fracture of the femoral neck speaks indirectly in favour of routine application of an endoprosthesis in the treatment of these fractures On the other hand, the ischaemic femoral head has a great loading tolerance (Sevitt & Thompson 1965) if the fracture is well reduced and rigidly secured, the femoral head will act as a biological endoprosthesis The problem is that the inadequacy of the present nailing technique and the continuous remodelling of the necrotic bone make most osteosynthetic methods unreliable Various compression techniques have been developed to aid the osteosynthesis of fractures of the neck of the femur (Brown & Abrami 1964 Rydell 1964, Muller et al 1965) The results so far reported are promising, but it should be noted that collapse of the femoral head also may occur after *stable osteosynthesis* in the late phase of repair, when revascularization has advanced into the weightbearing area of the necrotic femoral head (Catto 1965 b) Moreover, continuous pressure on a poorly vascularized femoral head *regularly results in flattening and derangement* of the trabecular structure, as has been observed in rabbits (Rokkanen et al 1965 Slatis & Rokkanen 1966) Similar observations were reported by Charnley (1961), who used compression osteosynthesis in the treatment of fractures of the neck of the femur

Subchondral OTC uptake in the femoral head is an interesting phenomenon, previously observed in experimental studies in the rabbit (Slatis & Rokkanen 1966) It seems to indicate that subchondral can

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EXAMINATION OF THE VASCULAR DISTURBANCE OF THE FEMORAL HEAD FOLLOWING INTRACAPSULAR FRACTURE OF THE HIP

A Preliminary Report Using a New Isotope Complex

E Korvald & A J Sundsfjord

Accepted 13 xii 73

Post-traumatic necrosis of the femoral head following a medial neck fracture has long been a challenge to investigators Many theories have been put forward and several methods have been tried in an effort to predict the viability of the head following such a fracture Hitherto none of the methods used have been sufficiently easy or rapid and reliable enough for clinical application

Recently Subramanian et al (1972) published a preliminary report using 99mTc labelled polyphosphate as a skeletal imaging agent The deposition of the 99mTc stannous polyphosphate in the bone is primarily a function of the bone blood flow as well as of the clearance of the isotope complex Therefore a decreased radioactivity would be anticipated in the caput region if vascularization is impaired, e g after certain fractures of the femoral neck

The purpose of the present investigation was to examine whether this new isotope complex may be used to study the vascular supply of the femoral head

METHODS

99mTc stannous polyphosphate was supplied by Nyegaard & Co A/S Oslo or obtained from New England Nuclear Corporation (Code NRP 158) The 99Mo/99mTc generators (30–50 mCi) were obtained from Institutt for Atomenergi Kjeller, Norway (Code TeCS) The isotope agent was prepared according to the instructions (Code NRP 158) A dose of 8–10 mCi was given intravenously immediately after preparation of the agent Photoscintigraphy was performed 3–4 hours after

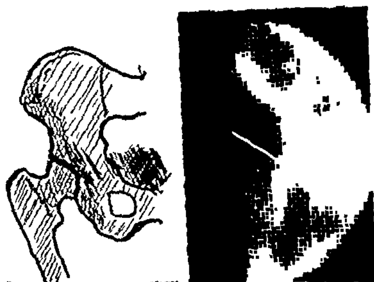


Figure 1 Drawing of a normal pelvis and hip Scattered areas show increased radioactivity over the bony parts To the right a photoscintigram of a normal non traumatized right hip



Figure 2 Intracapsular neck fracture with moderate dislocation. The scintigram shows normal and uniform radioactivity over the femoral head region



Figure 3 The same patient as shown in Figure 2 after application of a Christiansen endoprosthesis Reduced radioactivity over the head of the prosthesis

administration of the dose, using a gamma camera (Nuclear Chicago, Pho Gamma III) fitted with a parallel hole collimator (4000 holes) The urinary bladder was emptied immediately before the scintigraphy

MATERIAL

16 patients were investigated 15 had fractures, 14 of them having fractures through the upper end of the femur Most were females over 70 years The isotope examination was in most cases performed before reduction and nailing Both the fractured and the non traumatized hip were examined in every patient

The administration of the isotope and the scintigraphy were entirely discomfort free from the point of view of the patient The scintigraphy of both hips was run for approximately 20 minutes and the result printed as a photographic picture

RESULTS

Some of the findings are shown and described in Figures 1–7

Figure 7 shows the result in a one-year old medial fracture of the left hip, which had been nailed, primarily, in a fairly good position The fracture failed to heal, the nail became loose and was therefore removed The X-ray fifteen months after the trauma shows necrosis of the caput and a pseudarthrosis in the collum femoris The isotope



Figure 4 A medial neck fracture heavily dislocated with reduced radioactivity over the femoral head region

scintigraphy indicates an increased radioactivity in a zone around the caput femoris but in the middle of this region the radioactivity seems to be reduced

Several other intracapsular hip fractures have been examined Some show reduced radioactivity, others have normal radioactivity over the femoral head region Lateral neck and inter or pertrochanteric fractures all showed normal radioactivity over the region of the femoral head on the photoscintigrams Trauma to the hip without fracture also revealed normal photoscintigrams Isotope examination of the non traumatized hip showed in all cases uniform and normal radioactivity over the caput region

DISCUSSION

Technetium 99m is a short lived (half life 6 h), low energy (140keV) isotope without primary beta emission The radiation to the total body with the standard diagnostic test compares favourably with that of other nuclides used for bone scintigraphy, e g ^{18}F and several strontium nuclides The agent can be easily prepared locally, and the procedure is without discomfort to the patient The rapid and high rate



Figure 5 An impacted neck fracture with reduced radioactivity over the femoral head region

of clearance from the blood and deposition in the bone make it very useful for this particular purpose

Almost all of the isotope is cleared from the body by the urine Disturbing radioactivity will after a while be collected in the bladder as one can see in several of the photoscintigrams presented It is therefore important to empty the bladder immediately before the scintigraphy is performed

If the patients moved about a great deal during the 4 hours which elapsed between injection of the isotope and the scintigraphy, photograms were obtained in which the bony parts were barely visible This might be due to enhanced clearing of the isotope from the bony parts with the increased regional blood flow during exercise

It has been shown previously, by various methods, that the development of capital necrosis is caused by interrupted vascular supply to the femoral head It seems obvious that the vascular supply is more often disturbed *in medial and heavily dislocated fractures* because of the vascular pattern of the femoral head and neck Repositioning tends to improve the circulation, but often the femoral head seems to remain deprived of its vascular supply in spite of correct repositioning and nailing

Capital necrosis after neck fractures may develop *in as many* as

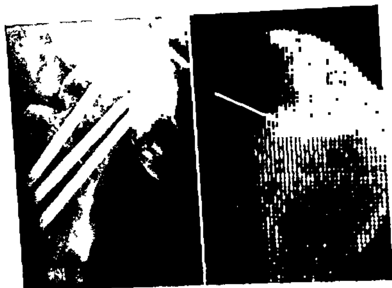


Figure 6 A nailed impacted intracapsular fracture of the femoral neck with increased radioactivity 10 weeks postoperatively



Figure 7 One year-old fracture of the left femoral neck with necrosis of the femoral head and pseudarthrosis Reduced radioactivity centrally in the femoral head region

30–40 per cent of the patients The necrosis which develops over several years may be of great discomfort to the patient, and the treatment of these patients often necessitates several, long lasting hospital stays It would therefore be a great advantage if it were possible to

predict which of the hip fractures would lead to necrosis. It would be a considerable improvement if these patients could initially be given the treatment which is ultimately necessary e.g. fitting with an endoprosthesis.

The 99mTc-polyphosphate complex has the advantage that its localization in the bony parts seems to depend mainly on the vascularization. The method described using this isotope and a gamma camera gives a visualized answer in about 20 minutes. It is our impression that the photoscintigrams give a picture of the nutrition of the femoral head which corresponds well to the degree of vascular disturbance after a fracture.

Whether or not this method permits prediction of a later development of an avascular necrosis of the femoral head is still an unanswered question. To solve this problem it is necessary to follow a series of patients with isotope scintigrams, X-rays and clinical examinations for at least 2 or 3 years. However, the isotope technique presented seems to be a rapid, easy and promising method worthy of further investigation.

SUMMARY

A preliminary report is given of the findings with 99mTc-labelled polyphosphate as an isotope method to determine the vascular supply of the caput femoris following fractures of the femoral neck.

It seems to be a rapid and easy method for visualizing the bony parts. Whether or not reduced radioactivity of the femoral head region indicates later development of avascular necrosis of the caput is a question which still remains to be answered. However, the method seems to be promising.

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PRIMARY ARTHROPLASTY IN FEMORAL NECK FRACTURES

A Review of 269 Consecutive Cases Treated with the Christiansen Endoprosthesis

HELGE KAVLIE & BJØRN SUNDAL

Accepted 6 xi 73

The results of the conventional treatment of femoral neck fractures have been disappointing in a high percentage of cases, as reported by Jensenius (1956), Nielsen & Jensen (1964) and Ramstad from this hospital (1966).

This led to a change in the treatment of femoral neck fractures in this hospital in the early 1960's. Since the Christiansen Endoprosthesis was developed in 1965, this prosthesis has been used routinely in the primary treatment of displaced femoral neck fractures in patients 70 years of age and older.

It is the purpose of this article to report our experience with this treatment over an eight year period (1965–1973) in altogether 269 arthroplasties on 263 patients.

METHODS AND MATERIAL

Indications

Arthroplasty has been used as the primary operation for the following indications:

a. Patients 70 years of age and over with displaced intracapsular femoral neck fractures.
b. In younger patients with similar fractures when associated medical or mental conditions make early ambulation essential or where avoidance of weightbearing could not be expected.
c. In younger patients when the fracture could not be reduced under anaesthesia.
d. In pathological fractures.

Excluded were patients who had not been walking prior to sustaining their fracture or who were moribund at admission. Patients with impacted fractures without displacement were treated by nailing, if at all.

predict which of the hip fractures would lead to necrosis It would be a considerable improvement if these patients could initially be given the treatment which is ultimately necessary e g fitting with an endoprosthesis

The 99mTc-polyphosphate complex has the advantage that its localization in the bony parts seems to depend mainly on the vascularization The method described using this isotope and a gamma camera gives a visualized answer in about 20 minutes It is our impression that the photoscintigrams give a picture of the nutrition of the femoral head which corresponds well to the degree of vascular disturbance after a fracture

Whether or not this method permits prediction of a later development of an avascular necrosis of the femoral head is still an unanswered question To solve this problem it is necessary to follow a series of patients with isotope scintigrams, X-rays and clinical examinations for at least 2 or 3 years However, the isotope technique presented seems to be a rapid, easy and promising method worthy of further investigation

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A preliminary report is given of the findings with 99mTc-labelled polyphosphate as an isotope method to determine the vascular supply of the caput femoris following fractures of the femoral neck

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The age distribution with mortality rates is shown in Table 1 In the subsequent discussion the patients are divided into two groups

Group 1 Patients who had plastic capitulums inserted and where the shaft piece was not cemented in place. These operations were carried out from 1965–1968 and the group comprises 115 arthroplasties

Group 2 Patients who had the present model of the prosthesis inserted with a metal capped capitulum and where the shaft was cemented in place with acrylic cement These operations were carried out from 1968–1973, and this group comprises 154 arthroplasties

The patients were seen postoperatively at 3 month intervals later 6-monthly and yearly each time with clinical and radiological examinations and with a grading of the results. Patients who had not been seen within the previous 3 months by the authors were recalled and personally examined and evaluated Thus 193 patients were personally examined and evaluated including patients who had been seen during the 3 last months of their lives.

Table 1 Age distribution and mortality rates at one and six months postoperatively related to age

Age	No of arthroplasties	Mortality		
		At 1 month	Between 1 and 6 months	Total mortality
60–64	11	0	1	1/11
65–69	32	2	2	4/32
70–74	53	5	1	6/53
75–79	84	8	11	19/84
80–84	51	8	6	14/51
85–89	27	6	6	12/27
90 and older	11	3	3	6/11
Total	269	32	30	62/269

Patients who did not return for examination were asked to complete a questionnaire with enquiries concerning hip mobility whether they were ambulant and if so what kind of support was needed if any and finally whether they had any pain on the operated side Where the patient had died enquiries were directed to the relatives or to the medical attendant In 58 instances the evaluation was made based on information from the questions together with the findings at earlier examinations

In 18 instances no adequate information could be obtained In those cases the result found when the patient was last examined and the period of observation up to that date were recorded

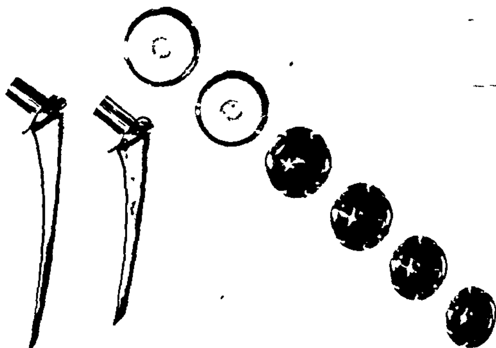


Figure 1 The Christiansen Endoprosthesis (current model) Two additional shaft pieces are now produced (see text)

The prosthesis

The present Christiansen Endoprosthesis (*Figure 1*) consists of a shaft piece of Francobol produced in two lengths (130 and 160 mm), and now also with a shaft model with a narrow stem and further a special long shaft piece (260 mm) A cylindrical trunnion is integral with the upper end of the shaft piece, fitting into a corresponding recess in the capitulum The capitulum is made of Delrin (plastic) fitted with a Francobol cup The axis of the trunnion with the capitulum and the principal axis of the shaft forms an angle of 115 degrees The capitulum comes in six sizes from 44 mm diameter with 2 mm increments up to 54 mm

The shaft piece is now cemented in place with acrylic cement used in this series since 1968

Originally the capitulum was made from Teflon and later from High Density Polyethylene Since 1968 it has been provided with a metal cap

Patient material

269 arthroplasties were carried out on 263 patients with fresh, displaced femoral neck fractures from 1965 up to January 1973 The operation was carried out on males in 42 instances and on females in 227 instances

ability to walk without support Although these medical disorders affected the grading in an adverse direction the result, as far as hip pain and movement is concerned, could be excellent

Table 2 Results in group 1 Patients with plastic capitulum pieces and without acrylic cement fixation

	Observation period (in years)								
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	Total
Excellent	2	1	0	0	0	1	0	0	4
Good	9	2	2	0	3	3	7	1	27
Fair	3	7	1	4	2	7	4	1	29
Poor	7	3	5	11	7	5	5	1	44
Total	21	13	8	15	12	16	16	3	164

Excluded from the table are 11 patients who died within the first month after surgery

Table 3 Results in group 2 Patients with the present model of the prosthesis with a metal capped capitulum and acrylic cement fixation

	Observation period (in years)					
	0–1	1–2	2–3	3–4	4–5	Total
Excellent	15	12	18	9	8	62
Good	16	4	0	5	3	28
Fair	17	1	5	1	2	26
Poor	11	1	1	4	0	17
Total	59	18	24	19	13	133

Excluded from the table are 21 patients who died within the first month after surgery

In the first year there was a tendency for the patients to improve their graded results once they gained confidence in their 'new' hip joint Later in Group 1 there was a marked tendency for the graded results to drop with the passage of time because of the late complications discussed below

In Group 2 the graded results have tended to be very stable once the patient gained full confidence in the hip joint All grade drops have been secondary to a new medical disorder

Management

As soon as the patient is admitted to the hospital, routine assessment of the general condition of the patient is performed, including blood tests, ECG and chest films. Most patients are put on tibial traction, and operation performed within 24–48 hours of admission, but occasionally later if other medical conditions needing treatment are discovered.

Apart from the first 21 patients in the series where an antero lateral incision was used, a posterior operative approach has been utilized (modified Osborne). Otherwise the same techniques were used in the two groups except that no cement was used in the first group.

The femoral head is removed and measured with calipers. The medullary canal is prepared for the shaft piece with an attempt to accommodate the long model (160 mm). The femoral neck is trimmed to allow the shaft piece to rest snugly on the calcar, especially on the medial side. The capitulum is selected according to the measurements of the removed femoral head. The shaft piece is then cemented in place, the capitulum inserted on the trunnion and reduction accomplished. The joint capsule is sutured, a suction drainage placed through a separate stab wound in all patients, and the incision closed. The patients receive local and systemic antibiotics prophylactically, but no routine anticoagulation is given. Postoperative X rays are obtained on the day of operation.

On the day after surgery physiotherapy is started with gentle active range of movement exercises. Most patients get out of bed on the second or third post operative day, and ambulation with a walker is usually started on the third day. The patients are encouraged to use full weightbearing from the start, this has been our policy throughout the whole period. They then gradually advance to support with crutches and then sticks. Many use no support at the time of discharge from the hospital usually around three weeks after the operation. Many patients have had to stay longer usually because of other medical conditions and for social reasons.

RESULTS

The results were graded according to Love's classification (1963) as follows

Excellent Good range of movement, occasional or no pain, no support necessary for regular activity

Good Some limitation of movement, slight pain and support with a cane necessary for walking

Fair Considerable limitation of movement, moderate pain and support with a walker or crutches necessary for walking

Poor Bed or wheelchair patient

The results are shown in Tables 2 and 3.

In 121 instances the arthroplasties were carried out on patients with a concomitant significant medical disorder which interfered with their



Figure 2 X-ray of patient with the old model with a Teflon capitulum showing marked osteolysis with a working down of the shaft piece into the femur (8 years after insertion)

with moderate pain in the hip The eight patients with superficial infections were all treated successfully and have not subsequently shown evidence of a deeper spread

Dislocation of the prosthesis was seen in 5 instances Two occurred on the day of operation, one three days postoperatively after a fall, and two later One of the latter occurred 6 years postoperatively in a patient where the prosthesis had worked down into the femur to a considerable extent Reduction was accomplished successfully in four patients in two of them without subsequent dislocation, while in two dislocation recurred repeatedly The last patient refused attempts at reduction One of the dislocations occurred following an antero-lateral operative approach In an attempt to keep the incidence of dislocation as low as possible the femoral neck is left as long as is compatible with reduction without undue difficulty, so as to get a certain tension, and secondly the joint capsule is sutured carefully Abduction is maintained postoperatively with a special pillow between the knees until muscle tone is completely regained after the anaesthetic

A marked difference has been noted in the incidence of late complications in the two groups In the first group an appreciable foreign

COMPLICATIONS

The complications encountered are listed in Table 4. As would be expected the early complications in the two groups occurred with about the same frequency. It is noted that general complications in the pulmonary and cardiovascular systems were the most frequent That the incidence of these complications was not even higher is attributed to the policy of early physiotherapy and mobilization.

Table 4 Complications

	Group 1	Group 2	Total (with per cent)
General			
Deep venous thrombosis	8	12	20/269 7 %
Emboli	5	7	12/269 4 %
Bronchopneumonia	8	19	27/269 10%
Local			
Superficial wound infection	4	4	8/269 3 %
Deep wound infection	6	2	8/269 3 %
Haematoma	5	4	9/269 3 %
Dislocation	3	2	5/269 2 %
Late			
Soft tissue calcification	18	14	
Osteoporosis, osteolysis	43	2	
Late fractures	23	1	
Late deep infection	1	1	

The incidence of deep venous thrombosis might possibly have been reduced by routine anticoagulation, but it is feared that the incidence of wound haematomas followed by possible infection would then increase

As regards the local complications, the most feared one is deep infection To keep the incidence of infections as low as possible strict aseptic techniques are used As mentioned above both local and systemic antibiotics are used as well as suction drainage for two days

The use of acrylic cement has not increased the rate of infection On the contrary deep infection has only been seen in two of the last 154 cases, while it was seen in 6 of 115 cases without cement

Of the eight patients who sustained deep infections, two were treated successfully with antibiotics, two required removal of the prosthesis, three died from sepsis and one still has a draining sinus associated



Figure 3 X ray of patient with prosthesis with metal capped capitulum and acrylic cement fixation (5 years after insertion)

Long term follow up results after femoral head replacement are still few in number, although data are now starting to appear, as reported by Salvati & Wilson (1973) with observation periods of up to 20 years These data seem to indicate that there is little tendency for the graded results to deteriorate with longer periods of observation, unless caused by other medical conditions However, only few patients have been followed for such long periods, and large series are difficult to get as most arthroplasties so far have been carried out on patients 70 years of age and above with a short life expectancy and therefore a high percentage of cases are lost to long term follow-up Because of this uncertainty concerning the long term prognosis, the use of the prosthesis is still limited to patients 70 years and above with the exceptions mentioned We may well lower this age limit in the future

Theoretically one would expect that the increased friction between the prosthetic head and the acetabulum would result in a wearing down of the acetabular cartilage followed by arthritic changes and pain We consider that this wear will be reduced when using the Christiansen Prosthesis, as the main movement—that of walking—in this prosthesis takes place between the prosthetic head and the

body synovitis resulted from the wearing down of the plastic capitulum giving rise to a marked osteolysis A rotation movement of the shaft piece in the medullary canal probably also contributed to this osteolysis and caused the shaft to work downward into the femur shortening the extremity and giving the patient pain and reduced range of movement (Figure 2) The osteolysis was so pronounced that at least 23 patients sustained subtrochanteric fractures in relation to the prosthetic shaft while this complication has only been seen once in Group 2 and in that instance after an adequate trauma

Mortality

There was an early mortality of 32 patients after the 269 arthroplasties performed (11 7 per cent) Of these 20 died within the first 10 days after the operation the remainder between the 11th and the 30th days The causes of death were Bronchopneumonia in 19 patients cardio-vascular complications in 10 patients pulmonary emboli in two patients and in one patient the cause of death was uncertain

A further 30 patients died within the first six months after operation giving an overall mortality rate of 23 per cent in the first six post operative months The last 30 deaths were not considered directly related to the operation The mortality rate in the various age groups is listed in Table 1 and shows as expected a direct relationship to the age of the patient

DISCUSSION

There has been a general dissatisfaction with the results of the conventional treatment of femoral neck fractures e g Smith Petersen/Johansson nailing At this hospital 21 out of 150 patients thus treated during the years 1960 1965 were readmitted because of complications by January 1966 (14 per cent of the total) as reported by Ramstad (1966) Other authors report even higher incidences of complications as stated by Jensenius (1956) and Hunter (1969)

Ramstad found further that the period of hospitalization was shortened from an average of 40 days in patients treated by nailing to an average of 27 days in the early cases treated by arthroplasty at this hospital

These considerations led to a change in the treatment of displaced femoral neck fractures in 1965 and from then on the Christiansen Endoprosthesis has been used routinely for the indications outlined above



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There was an early mortality of 32 patients after the 269 arthroplasties performed (11.7 per cent). Of these 20 died within the first 10 days after the operation, the remainder between the 11th and the 30th days. The causes of death were: Bronchopneumonia in 19 patients, cardio-vascular complications in 10 patients, pulmonary emboli in two patients, and in one patient the cause of death was uncertain.

A further 30 patients died within the first six months after operation, giving an overall mortality rate of 23 per cent in the first six postoperative months. The last 30 deaths were not considered directly related to the operation. The mortality rate in the various age groups is listed in Table 1 and shows as expected a direct relationship to the age of the patient.

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There has been a general dissatisfaction with the results of the conventional treatment of femoral neck fractures e.g. Smith-Petersen/Johansson nailing. At this hospital 21 out of 150 patients thus treated during the years 1960–1965 were readmitted because of complications by January 1966 (14 per cent of the total), as reported by Ramstad (1966). Other authors report even higher incidences of complications, as stated by Jensenius (1956) and Hunter (1969).

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These considerations led to a change in the treatment of displaced femoral neck fractures in 1965, and from then on the Christiansen Endoprosthesis has been used routinely for the indications outlined above.

Altogether 32 patients died in the first postoperative month, giving a mortality rate of 11 7 per cent. A further 30 patients died in the next five months giving a total six month mortality of 23 per cent, showing what a serious trauma a femoral neck fracture is in the elderly patient. The mortality rate was directly proportional to the age of the patient (Table 1), which has also been recorded by other authors, notably, Reno & Burlington (1958)

In comparison with the early mortality rate of 11 7 per cent Ramstad (1966) reported a mortality rate of 11 per cent at this hospital in the period 1960–1965 in 150 patients 70 years of age or older treated by Smith Petersen/Johansson nailing. These figures indicate a fairly equal mortality rate with these two operations Although the arthroplasty is an operation of greater magnitude, the anaesthesia time is probably fairly similar, and with the possibility of earlier mobilization and ambulation in the patients treated by arthroplasty, what may be lost by the greater operative trauma is probably gained in the postoperative period

The mortality rate in this series compares favourable with that reported by other authors (Greer & Niemann 1971, Nielsen & Jensen 1964 and Reno & Burlington 1958), while Hinchey & Day (1964) report lower mortality rates It is considered that early operation and early mobilization are extremely important in keeping the mortality rate down

In conclusion it is felt that primary arthroplasty in displaced intracapsular fractures of the femoral neck has been a significant advance in the treatment using the present prosthesis and acrylic cement fixation The mortality rate is about the same as with the conventional nailing, the postoperative care is easier, the patient can use full weightbearing from the start, the period of hospitalization has been shorter, and the late complications are much rarer with the need for secondary procedures just about eliminated The results in patients followed for more than one year were excellent or good in 80 per cent of cases. However, complications may be severe, notably deep infection, and the long term outlook is still uncertain, although there are observations indicating that the graded results tend to be stable after up to 20 years observation

SUMMARY

A review of the experience in 269 consecutive primary arthroplasties for displaced intracapsular femoral neck fractures using the Christian-

trunnion rather than between the head and the acetabulum, as is the case with most other current models (Christiansen 1969) The trunnion has been inspected after up to five years' use with no demonstrable wear

The early results in the first group operated in the period between 1965 and 1968 were promising as reported by Ramstad (1969) However, subsequent follow-up has shown a steady deterioration in the graded results because of wear and abrasion or cold-migration in the plastic material of the capitulum The shedding of microscopic particles of the plastic material caused a marked foreign body synovitis with osteolysis, as has also been demonstrated by histologic examination in several of our patients The osteolysis resulted in late fractures and a shortening of the extremity as mentioned previously These changes started to appear after an observation period as short as 18–24 months When the described complications were noted, the capitulum of the prosthesis was equipped with a metal cap, and cementing of the shaft piece was begun, both in 1968

Comparison of the late results after these alterations were carried out shows a marked difference, even if the follow-up for this group is shorter Still, after up to five years' observation, late complications similar to those noted in the first group have not been detected (Figure 3)

Some osteoporosis has been seen on two occasions in the second group, while advanced osteolytic changes were apparent in 43 patients in the first group Only one patient has had a fracture in relation to the prosthesis (after an adequate trauma) in the second group, while this occurred in at least 23 patients in the first group Soft tissue calcification has been noted in both groups, but more frequently in the first group

Having eliminated most of the above mentioned late complications using the present model of the prosthesis with acrylic cement fixation, the follow-up results have improved dramatically with 90 out of 133 patients graded as excellent or good (68 per cent) Of the remaining 43 patients with only fair or poor results 28 had other significant medical disorders, which interfered with their ability to walk without support Also 13 of the 43 were 80 years of age or older

If the patients observed less than one year are excluded, 59 out of 74 had excellent or good results (80 per cent), while 14 out of 15 not so classified had another medical disorder interfering with their function

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Department of Orthopaedic Surgery O, Odense Hospital, Denmark

INTERTROCHANTERIC DISPLACEMENT OSTEOTOMY

Metallic Failure Following Osteosynthesis

OLE SCHOLSBO

Accepted 25 ix 73

Metallic failure is extremely rare in intertrochanteric displacement osteotomy In the cases reported it has occurred in connexion with non-union, invariably in the form of plate failure (Rosborough & Stiles 1967, Scott 1967), according to Scott a secondary consequence of the non-union, i e a stress fracture Rose et al (1972), however, in a metallurgic analysis of a plate fracture in non-union, found the cause to be a combination of stress and corrosion No data are available as to whether the screws may fail also, as in the unstable intertrochanteric fractures (Foster 1958)

It seemed appropriate, therefore, to report the frequency of metallic failure in intertrochanteric displacement osteotomies fixed by 3 different types of implants, followed up by a metallurgic examination of the metallic failure

MATERIAL

During the 15-year period from 1957 to April 1972 a total of 496 intertrochanteric displacement osteotomies were performed in the Department of Orthopaedic Surgery Odense University All the osteotomies were performed by the same operative technique but concurrently by three different fixation methods After the operation non weightbearing was enforced for at least 3 months and weightbearing was not allowed until radiography revealed union

During the 11 years from 1957 to 1968 the fixation method was by the Bosworth apparatus made of vitallium which was applied to 125 osteotomies These were followed by non union in 9 cases but there were no instances of plate failure In one case a screw broke while being inserted.

During the 7 years from 1965 to April 1972 (and onwards) a special technique has been in use viz compression osteosynthesis and fixation by McLaughlin's apparatus made of vitallium Using this method 278 osteotomies were performed After 1970 there have been 2 cases of non union but not one of metallic failure

In both groups screws of a 3 54 mm diameter were used

sen Endoprosthesis is reported The indications for its use are listed and the prosthesis described The patient material is divided into two groups Group 1 Patients who had an older model of the prosthesis inserted without cementing of the shaft piece Group 2 Patients who had the present model of the prosthesis inserted with acrylic cement fixation of the shaft While the late follow up results were very dis appointing in the first group, those from the second group are con sidered most encouraging The early and late complications with mortality are discussed In conclusion it is felt that primary arthro plasty is a significant advance in the treatment of displaced femoral neck fractures in the elderly patient

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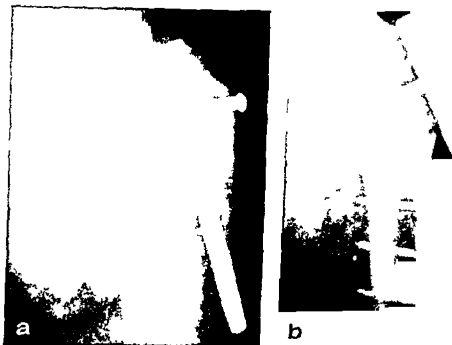


Figure 1 a, b Total screw failure with instability at the osteotomy site a few days after the operation

During the 4 years from 1968 to April 1972 (and onwards) a fixation and compression method—the Wainwright Hammond apparatus—was used in a total of 93 cases In the first 20 cases the material was titanium, and the screw diameter was 3 97 mm, viz 0 4 mm larger than that used so far After these first 20 cases vitallium was substituted for titanium because in 5 out of the 20 cases the screws broke, resulting in instability at the osteotomy site The 5 breakages occurred from two weeks to 3 months after the operation (Figures 1 a, b 2 a, b, c) All the patients had been complaining of pain right from the time of operation, and the cause was not disclosed until radiography was performed

Since that time 73 osteotomies have been performed using the Wainwright Hammond apparatus made of vitallium with a diameter 3 97 mm as in the titanium apparatus There have been no screw failures since the vitallium apparatus was introduced, and no cases of non union have been observed

ANALYSIS

To elucidate whether the screw failure might be due to causes other than the lesser hardness of titanium, 8 titanium screws 3 8 cm in length, 2 single-slot and 6 cross-slotted, 8 titanium screws 4 4 cm in length, 4 single-slot and 4 cross slotted, and 2 broken titanium screws



Figure 2 a b c. Screw failure 3 months after the operation. The osteotomies have united in a varus position.



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profile of the titanium screws had sharp transitions Moreover, the *fracture* surfaces in the broken screws showed that these *were not* fatigue fractures, but had to be considered fragility fractures Measurements showed a variation of 0 3 mm in diameter for the titanium screws This variation was less than 0 1 mm for the vitallium screws Tension was tested by supporting the screw head in a *tool*, and the tension was transferred to the screw tip From Table 1 it may be seen that the tensile strength is greatest for titanium 3 8 single slotted screws and least for titanium 3 8 cm cross slotted screws whereas the vitallium screw was midway between In the metallographic investigation it was discovered that the screw having the greatest tensile strength titanium 3 8 cm single slot was a chrome nickel steel screw

Table 1 Results of tension testing by the National Institute for Testing of Materials Copenhagen

Sample designated	Screw length (cm)	Tensile strength (approx kp)
Titanium single-slot	4 4	560
Titanium cross slotted	4 4	445
Chrome nickel single-slot	3 8	852
Titanium cross slotted	3 8	500
Vitallium cross slotted	4 4	638
Vitallium cross slotted	3 8	600

The conclusion of the National Institute was that it would serve no purpose to continue the investigation, as our store of titanium screws had to be considered inapplicable unless it was sorted It was investigated then whether it was the titanium screw which breaks because of its *insufficient strength or* whether *it is the* chrome nickel screw which breaks because it is too hard According to the estimate of the National Institute, neither screw was of a satisfactory workmanship The vitallium screws appeared to be of a more reliable make than the titanium screws

DISCUSSION

As non union is a presupposition for a stress *fracture, it is important* to obtain primary union This depends upon several factors The risk of non union is increased by *too* marked a displacement, a steep osteot

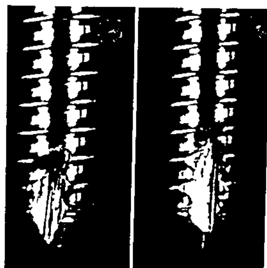


Figure 3 a Titanium screws with sharp thread profiles and muzzy cut (× 7.5)

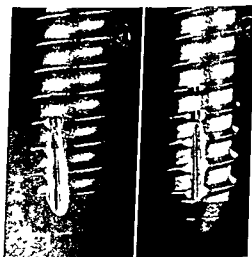


Figure 3 b Vitallium screws with round thread profiles and sharp cut (× 7.5).

were sent for examination to the National Institute for Testing of Materials in Copenhagen All the screws had been removed from the original packing For comparison (Weismann 1971), 6 vitallium screws 3 8 cm in length, cross-slotted, and 6 vitallium screws 4 4 cm in length, cross-slotted, were sent as well All the screws were of the same diameter, viz 3 97 mm

From the National Institute report it was apparent that on inspection there was a difference in the appearance of the self-tapping flute in the screw tips (Figure 3 a, b) The vitallium screws had a sharp, pure flute, the titanium screws a frayed, somewhat muzzy flute The thread

In the 5 cases in which the implant was removed the plates were in the same state as when inserted There was no reaction around the implants, no blackening of the tissue as described by Emneus & Gudmundsson (1967) As there were no signs of corrosion, presumably because of the short time the implant had been in situ (two weeks to nine months) further investigations of the plates were not carried out

SUMMARY

496 intertrochanteric displacement osteotomies were analysed for metallic failure The osteotomies are distributed between 3 concurrent fixation methods 125 using Bosworth's apparatus 278 using McLaughlin s apparatus and 93 using Wainwright Hammond s apparatus No metallic failure occurred among the cases treated by Bosworth s and McLaughlin s apparatus made of vitallium Among 20 osteotomies fixed by Wainwright Hammond s apparatus of titanium, screw failure occurred in 5 cases In all 5 cases this resulted in instability of the osteotomy Two patients required re osteosynthesis, whereas in 3 cases it proved sufficient to remove the implant, as the osteotomy had united The screw failures were analysed at the National Institute for Testing of Materials in Copenhagen where the cause was found to be poor workmanship of the screws

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Rose R M Shiller A L & Ratin E L (1972) Corrosion accelerated mechanical failure of a vitallium nail plate *J Bone Jt Surg* 54-A 854–862

omy line, and varus osteotomy as well as weightbearing too soon (Rosborough & Stiles 1967, Scott 1967, Green 1967, Holst-Nielsen et al 1972)

In a mixed osteotomy material of 108 osteotomies Rosborough & Stiles had 14 cases of non-union In 6 of these cases there was plate failure, of which 3 were fixed angular plates and 3 were straight plates, whereas with a variable angular plate (McLaughlin) there were 3 cases of non-union without metallic failure This finding was confirmed by Scott who observed fracture of a fixed angular plate in 9 out of 12 cases with non-union, but with a straight plate fracture occurred in only one patient out of 9 In the present material treated by Bosworth's and McLaughlin's apparatuses, there was no metallic failure in 11 cases of non-union, and this is in keeping with what has been reported in the literature

In the Wainwright-Hammond group the causes of screw failure were analysed metallurgically They proved to be not exclusively the lesser strength of titanium Insertion of the screws was prepared by drilling with a 3 2 mm burr There is a variation in the diameter of the titanium screws of ± 0 3 mm, the range being from 4 27 to 3 67 mm Considering also the poor workmanship of the screws, this causes an unnecessarily hard insertion in cases where the diameter is 4 27 mm Where the diameter is 3 67 the insertion will be looser In all, this gives rise to a varying tension along the plate If one screw fails, the other screws are likely to fail also There proved to be 2 chrome nickel screws in the material both single-slotted and 3 8 cm in length The screws had been removed from the original titanium packing, and they represented our remaining store of titanium screws The possibility of a packing fault is most likely, as the factory from which the material had been purchased manufactured the Wainwright Hammond apparatus in chrome nickel steel as well as in titanium They cannot have been derived from our own store of screws, as screws of a diameter of 3 97 mm have never been bought or used in the Department

The titanium screws used in the present material were of pure titanium In recent years stronger materials of titanium have appeared, in the form of titanium alloys, the most important ones being known as T 318® (a titanium, 6 per cent aluminium 4 per cent vanadium alloy) and T 680® (a titanium, 11 per cent tin, 2¼ per cent aluminium, 4 per cent molybdenum, 0 2 per cent silicon alloy) When heat-treated these alloys are superior to pure titanium in mechanical properties (Brettle et al 1971)

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Acta orthop scand. 45 599–613, 1974

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FUNCTIONAL STATUS OF THE LOWER EXTREMITY AFTER RESECTION OF FASCIA LATA

A Clinical and Physiological Follow-up Study in Patients with Fascia Lata Heart Valve Replacement

WIESLAW T DUBIEL & ANDERS WIGREN

Accepted 22.x 73

Since Senning in 1962 introduced the fascia lata in aortic valve surgery (Senning 1966), the use of autologous fascia lata in replacing the heart valves has rapidly increased (Ionescu & Ross 1969, Edwards et al 1969, Ross 1970, Dubiel et al 1973 a, b)

Fascia lata resection for the construction of one or more valves constitutes an extensive intervention on the support fascia of the leg What consequences can this have on the function of the leg? Does gait deterioration or other functional derangement occur in these patients and in that case how can it be prevented?

On the basis of these questions we have analysed the operative technique employed in the fascia lata resection, postoperative complications and late course in patients with fascia lata heart valve grafts Moreover a follow-up study which included clinical investigation, gait test and an isometric muscle strength test has been performed on 39 patients over a period of 1 3½ years after the operation

PATIENTS

During the period between Nov 13 1969 and June 7, 1972 84 resections of fascia lata were performed on 83 patients at the Department of Thoracic and Cardiovascular Surgery, University Hospital Uppsala

The following analysis comprises the first 57 patients Of these, 51 patients received ring supported fascia lata graft implantation in the aortic ostium, four received a graft in the mitral ostium and 2 received a graft in both the aortic and mitral ostia (Dubiel et al, 1973) The patient material comprised 18 females and 39 males ranging from 17 to 63 years of age with an average of 51 years

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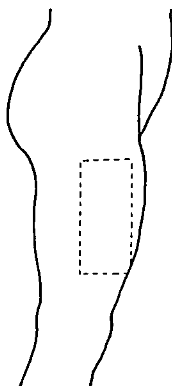


Figure 1 Illustration of the lateral contours of the operated leg The rectangle indicates the location and the size of the resected fascia lata piece Tractus ilio tibialis is left intact

A follow up study 1–3½ years after the operation included 39 patients of whom 15 were females and 24 males

METHODS

Technique of fascia lata resection

Under general anaesthesia resection of fascia lata was performed on the right thigh in 13 cases and on the left thigh in 44 The skin incision was approximately 25 to 30 cm long and stretched from approximately 15 to 20 cm below the spina iliaca anterior superior to about 10 cm above the upper margin of the patella The resected fascia lata measured approximately 10×20 cm The size of the fascia varied somewhat depending on the need as well as the quality In all cases, the fascia was removed from the middle third of the thigh (Figure 1) Preference was given to fascia from the lateral side of the thigh where the fascia is of greater tensile strength and its consistency is firmer After meticulous haemostasis and drain insertion the wound was primarily sutured in the first 10 cases This however resulted in large haematomas following heparinization during the bypass period of the heart operation Subsequently we have always packed the wound initially and delayed closure until completion of the heart operation and after giving protamine hydrochloride to neutralize the heparin effect Suction drainage (—10 to —15 cm H_2O) was left for 18 to 36 hours after the operation Simultaneously the thigh was bound with elastic bandages It was then recommended that the patient should wear a support dressing on the thigh for approximately six months A biopsy was taken from all the resections for a microscopic study

Clinical study

All patients were investigated by each of the authors with regard to the condition and the function of the operated leg. An attempt was made to record any possible injuries or disorders of the leg prior to the resection. The leg was investigated with regard to the condition of the excised area, the appearance of the scar, possible neuroma formation and sensory disturbances. Special attention was paid to the presence of residual fascia lata defect and muscle herniation. Muscle strength in the thigh and knee joint was estimated and the range of movement of the hip, knee and ankle joints was recorded. A general neurological examination was performed. Possible deviations in gait pattern were also observed. Thereafter the results from each of the authors were assembled.

Physiological study

Gait pattern analysis. The gait pattern analysis was performed only on 12 males between the ages of 19 and 65 years of whom seven were below the age of 50. Six of these patients had right sided fascia lata resection and six had left sided resection. Gait analysis was performed according to the method described by James & Öberg (1973). The measurements were made on a 20 meter long level floor covered by paper. The patient wore specially constructed shoes that were available in all sizes. The shoes were supplied with two micro switches, one placed back on the heel and the other on the tip of the sole. The switches were connected by long cables to an 8-channel electronic pen recorder (Elema Schonander Mingograph 81). Electric



Figure 2. Illustration of the typical appearance of the thigh after fascia lata resection. Proximal depression in the scar is probably caused by atrophy of the musculus tensor fasciae latae.

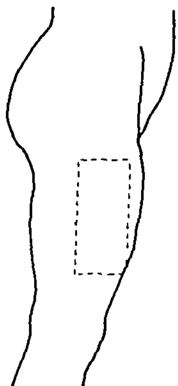


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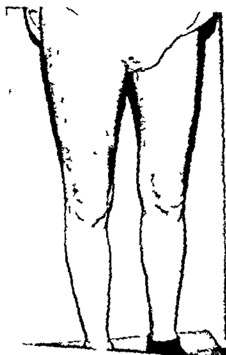


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impulses representing the beginning and the end of the stance phase for each leg were recorded on millimeter paper running at a speed of 50 mm/s While walking the heel prints of the patients were obtained with stamping ink During 5 consecutive walking cycles and under steady state conditions, various walking components such as the duration of the stance and swing phase, stride length and stride width were recorded The mean values of these 5 cycles were then calculated. From these parameters the walking speed and the step frequency were also calculated The patients were encouraged to use their normal walking speed during the experiment The material of Murray et al (1966), which included 30 normal subjects was chosen as a reference. Nomenclature and definitions used correspond to those employed by Murray et al (1966) Comparison was made with the non operated leg

Isometric muscle strength measurements Measurement of the maximal isometric muscle strength of the leg was performed on 34 patients, of whom 13 were females and 21 males between the ages of 18 and 65 years, the average being 48 8 years with 16 patients below 50 years The mechano electric force transducers were used as dynamometers (Pressductor®, ASEA, Vasterås, Sweden) The patients were investigated in a specially constructed chair on which dynamometers were mounted The measuring impulses were recorded by a one channel potentiometer recorder For further details the reader is referred to Backlund & Nordgren (1968) Under standardized conditions measurement of isometric muscle strength was performed in the following manner vertical pull downwards, vertical push upwards, hip flexion and extension, knee flexion and extension The measured parameters of the operated leg were compared with those of the non operated leg which served as a control No attempt was made to compare the present patient material with a normal reference material This is mainly due to the present patients' frequently long lasting heart diseases and old age The majority of patients (53 per cent) were in their fifties and sixties

RESULTS

Complications

Table 1 shows the postoperative and late complications in the leg where the fascia lata was resected Postoperative haemorrhage from the thigh incision necessitating reoperation occurred in 4 cases All these haemorrhages occurred in the first 21 patients of the series Superficial thrombophlebitis in the lower leg of the operated extremity developed in one case subsequent to the operation, while in another it occurred two months after the operation

Wound infection developed in 3 cases of which 2 had only mild infections, resulting in secondary healing within a period of 2 months Patient A 10 had a generalized bleeding tendency which necessitated several reoperations of the thoracotomy and thigh wound Infections of the thigh and sternotomy wounds, with growth of staph albus and E coli developed, together with an E coli bacteremia This patient

Table 1 Analysis of all complications following fascia lata resection in 57 patients who were subjected to implantation of fascia lata heart valves

	Sex	Age	Diagnosis	Operated leg	Early complications (within 28 days)	Late complications
	♀	54	AS	Right	Bleeding – Reoperation.	Superficial thrombophlebitis in the right leg
	♂	46	AI	Left	Bleeding – Reoperation Wound infection (Staph. albus, E. coli) Skin necrosis Septicaemia-Death.	
[illegible]	♀	45	AI	Left	Bleeding – Reoperation	
[illegible]	♂	27	AI	Left	Bleeding – Reoperation Trivial wound infection Prolonged wound healing	
[illegible]	♂	45	AI	Left	Superficial thrombophlebitis in the left leg	Meralgia paraesthetica Exaeresis nerv. cutan. femoris lat. sin.
[illegible]	♂	39	AS–AI	Left	0	Exudate in the left kne[e] arthrocentesis 2 x
[illegible]	♀	48	AS	Right	Wound infection Healed within 6 weeks	

— Aortic stenosis
— Aortic insufficiency
AI — Aortic stenosis and insufficiency

developed a purulent mediastinitis and died of sepsis two months after the operation

One patient had slight pains and paraesthesia surrounding the operation scar This necessitated excision of the nervus cutaneus femoris lateralis thus resulting in subsequent regression of the disorder

Preoperative fascia lata biopsy

In 55 cases the morphological picture was completely normal A heavy collection of round cells was found in one case however, neither rheumatic granuloma nor giant cells were detected This change was

Table 2 The objective findings in patients with orthopaedic compl

Case No	Sex	Age	Factors affecting the operated leg, not related to the resection of fascia lata	Present complaints	Fascial defe	
					Large	Sm
M 1	♀	59	Gonarthrosis before operation	Numbness of the R knee	0	
A 6	♀	56	Sciatica dxtr before operation	Paraesthesia and weakness of knee extension		
A 14	♂	19	0	Weakness (slight)		+
A 20	♂	49	0	Weakness	+	
A 22	♂	47	Claudicatio intermittens	Pain on walking		+
A 25	♂	44	Unspecified trauma in the operated leg in childhood Actual X ray 0	Weakness of hip flexion and knee extension Occasional pain on exertion	+	
A 36	♀	62	0	Weakness of knee extension		+
A 45	♂	40	Gonarthrosis before operation	Weakness	0	

difficult to interpret (non-specific inflammation?, clinical reaction after injection?) Partial fragmentation of the fascia with spaces between the collagen fibres has been found in another case, possibly due to oedema

Clinical study

Disorders in the operated leg were reported by 8 patients In Table 2 these disorders were analysed in relation to possible preoperative defects and to the objective findings In 4 patients the disturbances were related to *preoperative defects One patient had a positive* Babinski sign indicating central damage rather than an effect of fascia lata resection Two patients had disturbances that were related to the fascia lata resection

The period during which the patients wore a support dressing post-

ther with possible relationship to the preoperative defects

Muscle herniation		Clinical estimation of muscular strength	Neurological defect	Gait pattern	Isometric muscle strength as compared to the intact leg
(rest and during activity (large h.)	At rest only (small h.)				
	0	Normal	0	Normal	Equal
	0	Knee extension reduced	Pos. Lasègue sign (dxtr.)	Normal	Reduced 32 %
	+	Normal	0	Normal	Reduced 10 %
+		Normal	0	Normal	Reduced 20 %
	+	Normal	0	Normal	Reduced 12 %
+		Hip flexion and knee extension reduced	0	Normal	Reduced 14 %
	0	Knee extension reduced	Pos. Babinski sign	Normal	Reduced 11 %
	0	Normal	0	Normal	Reduced 12 %

operatively varied between 8 days and 1 year, although for the majority it was only 3 weeks (Figure 3).

Signs of secondary healing were detected in 8 patients. Symptoms of neuroma formations were not encountered. Movement restriction of the hip or the knee was not seen, neither was gait deviation observed in any of the patients. Table 3 presents certain objective findings in patients subjected to fascia lata resection. A permanent fascia deficiency comprising more than half of the resection area occurred in 5 cases and in all cases was closely related to muscle herniation which appeared not only during muscle relaxation but also during activity.

In 83 per cent of the cases with minor deficiency of the fascia lata small muscle herniation appeared. In 2 cases a decrease in muscle strength was noted during physical examination, which can be related to the fascia lata resection. A decrease in the strength of hip flexion and knee extension was found in one case, while in another only a

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difficult to interpret (non specific inflammation?, clinical reaction after injection?) Partial fragmentation of the fascia with spaces between the collagen fibres has been found in another case, possibly due to oedema

Clinical study

Disorders in the operated leg were reported by 8 patients In Table 2 these disorders were analysed in relation to possible preoperative defects and to the objective findings In 4 patients the disturbances were related to preoperative *defects One patient had a positive* Babinski sign indicating central damage rather than an effect of fascia lata resection Two patients had disturbances that were related to the fascia lata resection

The period during which the patients wore a support dressing post

ether with possible relationship to the preoperative defects

Muscle herniation		*Clinical* estimation of muscular strength	Neurological defect	Gait pattern	*Isometric* muscle strength as compared to the intact leg
t rest and during activity (large h)	At rest only (small h)				
0		Normal	0	Normal	Equal
0		Knee extension reduced	Pos Lasègue sign (dxtr)	Normal	Reduced 32 %
	+	Normal	0	Normal	Reduced 10 %
+		Normal	0	Normal	Reduced 20 %
	+	Normal	0	Normal	Reduced 42 %
+		Hip flexion and knee extension reduced	0	Normal	Reduced 14 %
0		Knee extension reduced	Pos Babinski sign	Normal	Reduced 11 %
0		Normal	0	Normal	Reduced 12 %

operatively varied between 8 days and 1 year, although for the majority it was only 3 weeks (*Figure 3*)

Signs of secondary healing were detected in 8 patients Symptoms of neuroma formations were not encountered Movement restriction of the hip or the knee was not seen, neither was gait deviation observed in any of the patients Table 3 presents certain objective findings in patients subjected to fascia lata resection A permanent fascia deficiency comprising more than half of the resection area occurred in 2 cases and in all cases was closely related to muscle herniation which appeared not only during muscle relaxation but also during activity

In 83 per cent of the cases with minor deficiency of the fascia lata small muscle herniation appeared In 2 cases a decrease in muscle strength was noted during physical examination, which can be related to the fascia lata resection A decrease in the strength of hip flexion and knee extension was found in one case, while in another only a

Figure 3 Illustration of the time during which the patients had worn a support dressing on the thigh and its relation to the possible emergence of muscle herniation The sex of the patients is indicated by the symbols ♂ ♀

decrease in the knee extension strength was detected Two cases had apparent paraesthesia surrounding the operation scar and nine had non-disturbing paraesthesia Minor neurological symptoms found in 2 cases were not related to the fascia lata resection

Physiological study

Gait pattern analysis Table 4 presents the mean values and range of walking speed, together with the duration of the walking cycle, step frequency, stride length and stride width found in 12 patients during the gait pattern analysis The values given by Murray et al (1966) were referred to for comparison Those patients investigated had a normal gait pattern when compared with normal subjects

In Table 5 mean values of the duration of the stance and swing phases are presented The step length is given in centimetres and per cent of the stride The values for each leg are presented separately and are further compared with the normal material of Murray et al (1966) No deviation in the operated leg, compared with the non operated leg, was observed, which means that a complete symmetry of gait, as in normal individuals, was present

Table 3 The objective clinical findings in 39 patients after the fascia lata resection

		Number of cases	Per cent
Fascial defect	Large*	5	13
Fascial defect	Small†	18	46
Muscle herniation	at rest and during activity	5	13
Muscle herniation	at rest only	15	33
Reduction of muscular strength	Knee extension	2 (2§)	5
	Hip flexion	1	3
Paraesthesia		11	28

* Large = Equal to or more than half the length of the skin scar

† Small – Less than half the length of the skin scar

§ Additionally 2 cases with objective signs not related to the resection of fascia lata Case A 6 with sciatica on the operated side and case A 36 with residual symptoms of hemiplegia on the operated side

Isometric muscle strength measurement Values obtained from 34 patients are presented in Table 6 Muscle strength in hip flexion and knee extension in the operated leg show a probably significant decrease ($0 05 > P > 0 01$) The other muscle functions investigated here did not show any significant difference between the operated and non-operated leg

Table 4 Gait variables in 12 males after the fascia lata resection and comparison with the respective variables found by Murray et al (1966) in 30 normal subjects

	Present material (no = 12) Normal walking speed M Range	Material of Murray et al (1966) (no = 30) Normal walking speed M (SD)
Walking speed cm/s	123 94–169	151 (20)
Walking cycle s	1 21 1 06–1 44	1 06 (0 09)
Step frequency steps/min	99 84–114	113
Stride length cm	148 4 129–185	156 (13)
Stride width cm	9 6	7 7 (3 5)

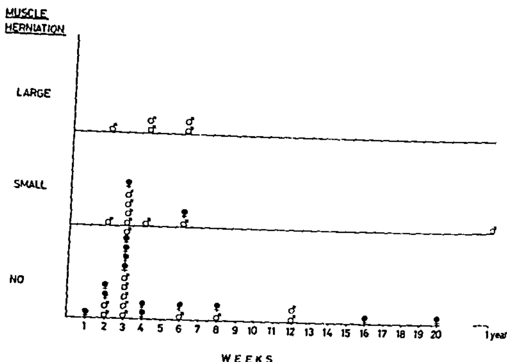


Figure 3 *Illustration of the time during which the patients had worn a support dressing on the thigh and its relation to the possible emergence of muscle herniation The sex of the patients is indicated by the symbols ♂ ♀*

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Table 6 *Isometric muscle strength in kiloponds in 35 patients after a one sided fascia lata resection*

Tests	Intact leg M, kp	Operated leg M, kp	Difference M SD SEM P	Difference Per cent
Vertical pull downwards	39 9	38.8	-1 1 5 4 0 9 >0.05	-2 8
Vertical push upwards	18 9	17 9	-1 0 3.8 0 7 >0.05	-5.3
Hip flexion	40 6	37 6	-3 0 7 5 1 3 0 02*	-7 4
Hip extension	37 2	36 0	-1.3 4 5 0 8 >0.05	-3 5
Knee flexion	18 4	17 8	-0 7 3 5 0 6 >0.05	-3 8
Knee extension	48 8	45 6	-3.3 7 9 1 4 0 02*	-6 8

M = Arithmetic mean value.
S D = Standard deviation
S E M = Standard error of the mean
X = $0.05 > P > 0.01$ (Probably significant)
XX = $0.01 > P > 0.001$ (Significant)
XXX = $0.001 > P$ (Highly significant)

Symptoms of meralgia paraesthetica were difficult to explain in terms of the fascia lata resection It is possible that the peripheral branches of the nervus cutaneus femoris lateralis had been injured during the operation

Table 5 Walking cycle components and step length in 12 males after fascia lata resection and comparison with the respective variables found by Murray et al (1966) in 30 normal subjects

	Present material (no = 12) Normal walking speed M		Material of Murray et al (1966) (no = 30) Normal walking speed M (SD)
	Intact leg	Operated leg	
Stance phase s	0 72	0 73	0 65 (0 07)
Per cent of cycle	60	60	61
Swing phase s	0 49	0 48	0 41 (0 04)
Per cent of cycle	40	40	39
Step length cm	74 4	74 0	78 0 (7)
Per cent of stride length	50	50	50

DISCUSSION

For a long time autologous fascia lata grafts have been used in various forms of reconstructive surgical intervention As a rule only small parts of the fascia are resected Thus little attention has been given to the possible local changes following fascia lata resection Construction of heart valves requires a large amount of fascia Thus in most cases in order to obtain a fascia piece free from vascular perforations and other defects the resected fascia must be 3 4 times larger than that required for the construction of a valve normally 3×12 centimetres Surplus fascia should be available for possible additional valves Due to this, the fascia defect is always large primarily and the local operative intervention is rather extensive

The early complication in this material was mostly haemorrhage with haematoma In heart operations with extracorporal circulation heparin is used Thus in primary closure of the wound even meticulous haemostasis is not effective Since attention was paid to the risks of haematoma, the operation techniques were modified and thereafter haematomas did not develop The importance of preventing haematoma is illustrated by the case where haemorrhage and haematoma probably contributed to sepsis with a lethal outcome

Superficial thrombophlebitis occurring in 2 cases had no definite relation to the resection although a surgical intervention in the leg is in itself a contributing factor to the emergence of thrombosis and thrombophlebitis Early physiotherapy is therefore important prophy lactically

During the follow up study no definite consequences of the early complications were established (Table 7)

Two young males had complaints which were directly related to the operation in the extremity Subjective muscle weakness during extension combined with slight pains was reported in one case Defect of the fascia with muscle herniation was found in both cases Clinically, the muscle strength decrease during knee extension and hip flexion was diagnosed in one of the two cases, while deterioration in the isometric muscle strength in hip flexion and knee extension occurred in both cases This mainly affected the functions that are mediated by the fascia lata from the musculus tensor fasciae latae and the musculus gluteus maximus Accentuation of disturbances related to preoperative defects might have occurred in some patients due to the fascia lata resection

Muscle herniation found in half of the patients investigated had neither functional nor as a rule, cosmetic importance Kleinschmidt (1914), Gratz (1937) and Foshee (1947) have found that fascia lata regenerates after the resection Foshee is of the opinion that "herniation will be prevented by the newly formed regenerated fascia" He claims that herniation developing postoperatively disappears after approximately six months, when the regenerated fascia is fully developed

In our material 50 per cent of the patients had muscle herniation—13 per cent had large herniation—observed after a period of 1–3½ years After such a long period of observation, the muscle herniation should be considered as permanent Of the 15 female patients only 2 had small muscle herniation (Figure 3) This is in contrast to Foshee's view that athletic individuals have better fascia regeneration Possibly the consistent use of a support dressing on the thigh for a long time would diminish the number of muscle herniations in our material (Figure 3) Re transplantation of surplus fascia, when possible, would be a further preventive measure, although not proven in this investigation

Gait analysis with recordings of various walking components, is a reproducible and objective method for revealing and analysing pathological deviations in gait pattern This method has been used on 12 males of various ages During the experimental conditions, i e level floor and self selected walking speed, no deviations from normal walking have been detected Thus the fascia resection does not seem to have affected the walking ability

Table 7 Analysis of the results of the follow up study of patients with complications following the fascia lata resection

Case No	Complaints	Clinical status	Gait pattern		Isometric muscle strength in comparison to the intact leg	Comments
			Clinical investigation	Physiological investigation		
A 6	Paraesthesia Weakness of knee extension	Small fascial defect Reduced muscular strength of the knee extension	Normal		Lowered 40 %	Sciatica dxtr before operation Positiv Lasègue sign
A 13	Paraesthesia	Small fascial defect	Normal		Equal	
A 19	0	Small fascial defect	Normal	Normal	Equal	
A 22	Intermittent pain in the calf	Small fascial defect	Normal		Lowered 42 %	Claudicatio intermittens
A 45	Weakness of knee extension	0	Normal		Lowered 12 %	Gonarthrosis before operation
A 48	0	0	Normal		Equal	

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Due to rather large age differences and permanent heart disorders, the absolute values of the isometric muscle strength test showed both inter- and intra-individual variations Therefore it has been of interest to compare the muscle strength of the operated leg with that of the non-operated leg Variations were found even here i e both very low or rather high values for the operated leg were obtained This was due to other defects such as osteoarthritis, vascular diseases, post embolisms and neurological disorders On the whole, no significant decrease in the muscle strength was found other than in hip flexion and knee extension i e for functions mediated by fascia lata

SUMMARY AND CONCLUSIONS

The effect of an extensive fascia lata resection on the function of the operated leg has been studied in 57 patients for whom fascia lata grafts have been used for heart valve replacement A follow-up study of 39 patients 1–3½ years after the operation included a clinical investigation, isometric muscle strength test and a gait test

1 An extensive fascia lata resection produces no serious functional disorders, except, possibly, in young active males
2 The frequent occurrence of muscle herniation seems to have only a cosmetic interest However it might be prevented by a long lasting consistent use of a support dressing on the thigh
3 Meticulous operative technique, reopening of the wound following neutralization of heparin, suction drainage for at least 18 hours postoperatively and early physiotherapy are recommended

ACKNOWLEDGEMENTS

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Our thanks to Kitty Wahlborg and Kurt Öberg for their help and assistance during the gait analysis

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able 1 *Distribution according to age, sex, disease and localization of bone specimens for hardness tests*

Normal				Osteoarthritis				Rheumatoid arthritis			
M		F		M		F		M		F	
MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC
1		3	1								
		1									
3	2	1	1								
2	1	1						3		2	1
2	1	1	1	3	2	2		2		2	1
		4	3	3	2	2		2	1	4	
3	3			2	1	3				1	
1						1					
12	7	11	6	8	5	8		7	1	9	2

medical condyle, LC — lateral condyle.
males, F = females.

All individuals had been fully active until shortly before death. In this group 23 medial and 13 lateral condyles were tested

Osteoarthritis Sixteen subjects with an age range from 62 to 91 years (see Table 1)

The diagnosis was verified by naked eye observation and radiology and based on cartilage destruction, osteophytes subchondral cysts and sclerosis

Ten cases were obtained at autopsy, the cause of death being myocardial infarction (5) pulmonary embolism (1) cerebral haemorrhage (1), pneumonia (2), and oesophageal cancer (1) Six cases were obtained at amputation for vascular disease.

All individuals had been mobile until shortly before the specimens were taken In this group 16 medial and 5 lateral condyles were tested.

Rheumatoid arthritis There are three factors to be considered when investigating bone specimens in rheumatoid arthritis

1 the stage of the disease,
2 steroid treatment and
3 immobilization.

Due consideration has been taken of these three factors in the selection of specimens from the 16 cases which have been investigated Of these, 15 were classified as classical rheumatoid arthritis according to the criteria of the American Rheumatism Association (1958) and one as definite

A general feature of rheumatoid arthritis is osteoporosis (Gardner 1972) Previously this has been believed to be in part due to steroid treatment (Chandler et al 1958 Edstrom 1961), but according to McConkey et al (1962) and Saville & Kharmosh (1967) the use of corticosteroids did not significantly increase the frequency of osteoporosis.

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HARDNESS OF THE SUBCHONDRAL BONE OF THE TIBIAL CONDYLES IN THE NORMAL STATE AND IN OSTEOARTHRITIS AND RHEUMATOID ARTHRITIS

PAUL LEREIM, IAN GOLDIE & ERIK DAHLBERG

Accepted 13 xi 73

During the last decade several authors have advanced the theory that bone changes come before cartilage destruction in osteoarthritis as alterations in bone could significantly affect the pressures exerted on the cartilage

Cartilage destruction is one of the hallmarks of rheumatoid disease Scant information is available on the histologic features of the subchondral bone in rheumatoid arthritis Murray (1969) has radiologically demonstrated subarticular decalcifications as early signs of rheumatoid arthritis To the best of our knowledge no investigations on the mechanical properties have been presented

We have embarked on an investigation the aim of which has been to analyse biomechanical, biochemical and morphologic features of subchondral bone in rheumatoid arthritis in comparison with normal bone and that in osteoarthritis

This presentation concerns the biomechanical part which deals with the measurement of hardness of subchondral, trabecular bone

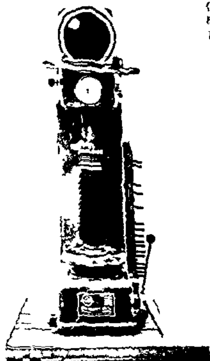
MATERIAL

Specimens have been taken from the medial and lateral condyles of the tibia and have been obtained at autopsy amputation and reconstructive surgery

Normal Twenty three subjects with an age range from 20 to 90 years (see Table 1)

The normal structure of the tibial condyles was ascertained by naked eye observation and radiology

Cause of death was myocardial infarction (8), cerebral haemorrhage (3) cancer not affecting the skeletal system (9), and various diseases (3)



← *Figure 2 a Micro hardness tester (Otto Wolpert Werke) used for hardness measurements of subchondral bone in tibial plateaus*

pyramidal formed diamond according to Vickers into the substance. We have used the Brinell method as described by v. Weingraber (1952), (Brinell 1900)

A steel ball with the diamater D in mm is pressed for a specific time with a load P in kp into the material (Figure 3). An indentation area A is formed and measured in mm². The Brinell value (HB) as measured in kp/mm² is the ratio of the load P to the indentation area A, i.e.

$$A = \frac{\pi}{2} D \left(D - \sqrt{D^2 - d^2}\right) = \pi D t$$

In this investigation the diameter of indentation area d has been used for the calculation.

The Brinell value can thus be written

$$HB = \frac{2P}{\pi D \left(D - \sqrt{D^2 - d^2}\right)}$$

For this investigation a steel ball with the diameter 5 mm has been used, and the load was 10 kp. The time for indentation was 15 seconds. This time was found suitable as the indentation area progressed during 5 seconds after which it re

In our investigation seven of the 16 cases had received steroid treatment for various lengths of time during the 5 year period prior to the taking of the specimen

All individuals had been actively mobilized In two there had been no weight bearing

The age range for the 16 cases was 53 to 86 years (see Table 1)

Six were obtained at autopsy the cause of death being cardiovascular in all Two specimens were taken at amputation because of circulatory failure and the remaining eight at reconstructive surgery

In this group 16 medial and 3 lateral condyles were tested

METHOD

The condyles were removed in one piece with a margin of 2–3 cm subchondral bone Immediately after removal the specimens were frozen to – 20° Centigrade a procedure which according to Sedlin (1965) and to Sedlin & Hirsch (1966) has no adverse effects on the physical properties of bone

Before submitting the specimens to the hardness test they were thawed in Ringer's solution After thawing the lower transected bone area was further prepared with a band saw to a plane that was parallel to the weightbearing articular surface The cartilage of the weightbearing area was then carefully removed with a chisel and knife to the calcified zone (To ascertain that this zone had been reached without interfering with the subchondral bone the zone was studied under a microscope Histologic verification of the exactness of this procedure was later obtained) The remainder was carefully ground away in Ringer's solution and the subchondral cortical bone was removed so that trabecular bone was reached (Figure 1) In this way one area of about 1 cm diameter within each condyle could be prepared for the hardness tests These were carried out on wet bone in room temperature with normal humidity

Hardness of a material can be determined by applying a specified load over a certain time and calculating the ratio of load to indentation area Practically this can be done by pressing a steel ball (Figures 2 a 2 b) according to Brinell or a

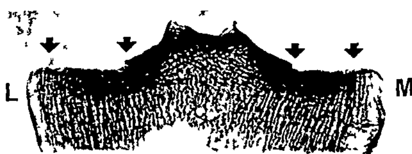


Figure 1 X ray of 5 mm thick slice of lateral (L) and medial (M) condyles of normal tibial plateau Cartilage and subchondral bone plate ground away between arrows

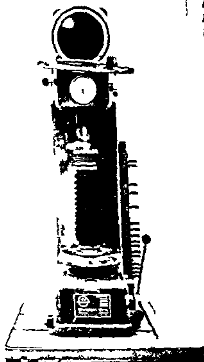


Figure 2 a. Micro hardness tester (Otto Wolpert Werke) used for hardness measurements of subchondral bone in tibial plateaus

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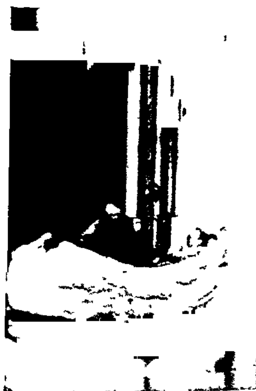
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The Brinell value can thus be written

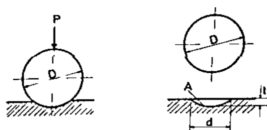
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Figure 2 b Close-up of steel ball for indentation test according to Brinell. The ball is pressed into the subchondral bone covered with pressure sensitive tape after removal of the cartilage and subchondral bone plate within the weightbearing area of the tibial plateau.



HARDNESS TEST ACCORDING TO BRINELL



HARDNESS, $HB = \frac{P}{A} = \frac{\text{FORCE}}{\text{INDENTATION AREA}}$

$A = \frac{\pi}{2} D(D - \sqrt{D^2 - d^2}) = \pi D t$

D = DIAMETER OF BALL
d = DIAMETER OF INDENTATION
t = DEPTH OF INDENTATION

$HB = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$ [kp/mm²]

Figure 3 Schematic demonstration of hardness test according to Brinell



Figure 4 a Indentation area (shadowed black one) as maintained on the pressure sensitive tape after indentation into hard material



Figure 4 b Same as 4 a but with indentation in softer material



Table 2. Mean Brinell hardness for normal bone, and that in osteoarthritis and rheumatoid arthritis at various ages Increase statistically significant at 95 per cent level

(Graphic demonstration in Figures 5–7)

Age	Normal	Osteoarthritis	Rheumatoid arthritis
20–29	5 7		
30–39	5 5		
40–49	5 6		
50–59	7 3		4 4
60–69	6 3	4 1	4 4
70–79	8 5	3 8	4 4
80–89	9 1	4 3	5 8
>90	5 7	3 1	

mained unchanged Three indentations were carried out on different sites and the mean Brinell value was calculated

The elasticity of bone is such that after impact a restitution to normal is so fast that the estimation of the indentation diameter can become jeopardized For this reason the area to be tested was covered with a polyester pressure sensitive tape which together with its adhesive layer measured 0 06 mm (Minnesota Mining and Manufacturing Comp) Thus the indentation in the bone could be maintained on the tape (Figures 4 a, 4 b) and measurements were made in a measuring microscope in two directions Mean calculations were made

In order to exclude the possibility of the tape deranging the true values from bone, tests were carried out on more homogenous organic materials such as oak birch and fir with and without the tape The values obtained showed no significant differences

Statistical method Student's T test One way analysis of variance (Statistical analysis = Ulf Runze, B A)

RESULTS

There was no significant difference in the Brinell values for the three indentations in each condylar area tested In the normal group the hardness increased significantly (95 per cent level) with increasing age, see Table 2 and Figure 5 No difference in sexes was observed and this applied as well to the osteoarthritis and rheumatoid arthritis groups

For the osteoarthritis and rheumatoid arthritis groups the hardness was significantly lower (99 9 per cent level) than in the normal state in corresponding age groups (see Table 2 and compare Figures 5 to 7). The mean difference in hardness values is seen in Table 3

The tests on the lateral condyle in the normal group showed

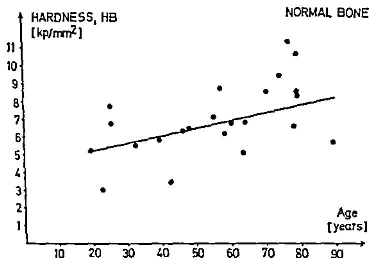


Figure 5 Hardness of normal subchondral bone of medial condyle of tibia in relation to increasing age no = 23

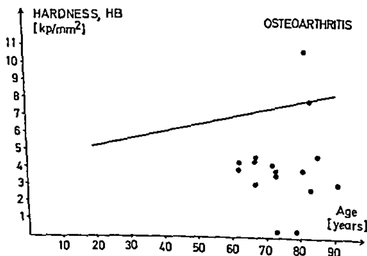


Figure 6 Hardness of subchondral bone of medial condyle of tibia in osteoarthritis no = 16 Regression line represents normal bone (cf Figure 5)

significantly (99 9 per cent level) lower hardness values when compared to the medial condyles (Figure 8)

No conclusions can be made as regards the difference in hardness of the lateral condyle between each group because of the small number tested

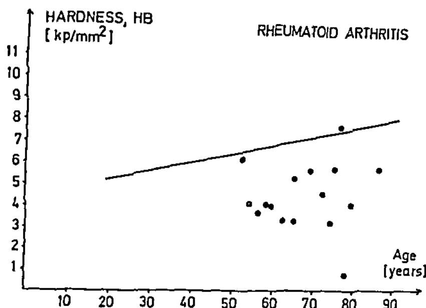


Figure 7 Hardness of subchondral bone of medial condyle of tibia in rheumatoid arthritis no = 16 Regression line represents normal bone (cf Figure 5)

In the rheumatoid arthritis material no difference in hardness was observed between the steroid treated and non-steroid treated groups The mean value for both groups remained the same and was 4 5 with SD = 1 7

The duration of rheumatoid disease did not appear to have any influence on the hardness (Figure 9) In two cases, however, the duration could not be determined

DISCUSSION

Hardness of bone is its capacity to resist the impact of a penetrating agent (Weaver 1966) According to Currey (1970) the hardness of bone varies with the strength, modulus of elasticity and the plastic flow

Table 3 Mean difference in hardness values (HB) for normal bone and that in osteoarthritis and rheumatoid arthritis

	Age	Normal	Osteoarthritis	Rheumatoid arthritis
HB	50–89 years	7 6±2 2		4 5±1 6
	60–91 years	7 6±2 3	3 9±2 5	

Difference at 99 9 per cent level between normal and rheumatoid arthritis and normal and osteoarthritis

No statistical difference between osteoarthritis and rheumatoid arthritis

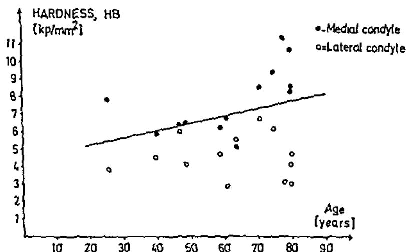


Figure 8 Comparison of hardness of normal subchondral bone in medial and lateral tibial condyles Regression line represents the medial condyle (cf Figure 5)

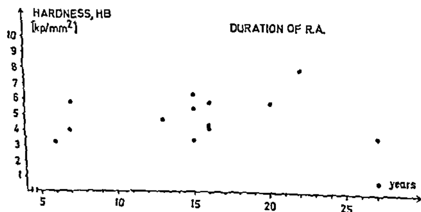


Figure 9 Hardness of subchondral tibial bone in relation to duration of rheumatoid process

that bone can undergo In 1954 Carlström published observations on microhardness of single Haversian systems These showed a varying degree of mineralization (previously demonstrated by Amprino & Engstrom 1952), and the hardness of each Haversian system was directly related to the degree of mineralization This was later confirmed by Amprino (1958) Weaver (1966) also determined the hardness of individual trabeculae of cancellous in comparison to cortical bone

Besides the direct correlation between mineralization and hardness he also demonstrated that cancellous bone was slightly more pliable than cortical bone

A factor influencing hardness is the number of osteons Evans & Vincentelli (1969) have shown a strong positive correlation between hardness and the number of osteons/mm² in cortical bone The same applies to trabecular bone (Weaver & Chalmers 1966)

Hardness decreases with age in cancellous bone (Evans 1961, Weaver & Chalmers 1966) No great difference exists between the two sexes below the age of fifty (Weaver & Chalmers 1966), over the age of fifty hardness and mineral content are significantly lower in women (Weaver & Chalmers 1966, Rockoff et al 1969). The cancellous bone loses its hardness sooner than reduction of bone tissue occurs (Evans & King 1957, Bell et al 1967)

The influence that disease has on bone hardness has been investigated by Weaver (1966) In *Paget's disease* the hardness differed at various sites and a good correlation was obtained with the histologic findings, i e severe changes—soft bone In *osteogenesis imperfecta* the bone was so soft that no measurements could be made, and in *osteoporosis* hardness was not significantly affected In *renal rickets* hardness was decreased in general, and most in the trabecular bone The latter might be due to the finding of De Luca (1973) that the kidney acts as an endocrine organ for the production of the actual calcium regulating hormone (1 25 dihydroxy-vitamin D_3)

The difficulty connected with the testing of physical properties in cancellous bone is due to the lack of homogeneity in the trabecular structure, which e g aggravates testing conditions for tensile strength as gripping the cancellous structure is almost impossible without crushing it Likewise difficulties arise in indentation tests as the removal of cartilage often results in serious intervention with the trabecular network The subchondral bone of the tibial condyles enables the removal of the over-lying cartilage without interference with the trabeculae Other reasons for choosing the medial tibial condyle was *that* it belongs to one of the more loaded joint systems of the body, *that* it most often becomes the site of osteoarthritis affecting the knee joint and *that*, according to theoretical calculations, the compression forces are about ten times larger medially than laterally It moreover lends itself without too great technical difficulties to indentation tests and for these reasons the tibial condyles have been used in this investigation

In our series the hardness increased in the normal material with advancing age This is in opposition to previously published observations (Evans 1961, Weaver & Chalmers 1966) which pointed to a decrease with age We have not been able to find a rational explanation of this difference However, there is a difference in the technique other authors have been testing the microhardness in single Haversian systems and single trabeculae which have a rather homogenous structure, while we were testing a network of trabeculae Nevertheless, if one accepts the dependency of hardness on the degree of mineralization some investigations report in favour of hardness of bone increasing with age In 1957 Robinson & Elliot could demonstrate that an increase of the mineral content occurred with age at the expense of the water content, leaving the content of organic material per volume unaltered Later this was verified by Strandh & Norlen (1965) who showed that the calcium content per unit weight or volume increased with age up to the 50th to 70th year and parallelled density Furthermore Bergstrom & Bell (1954) demonstrated that the carbonate content of bone increased with age Thus, there is evidence that mineralization can augment with advancing age and consequently the hardness of bone should increase as the data in our normal material suggest In our further studies of this material, consideration will be taken of the degree of mineralization

There is a difference between the normal group and the osteoarthritis and rheumatoid arthritis groups The diminished hardness of the trabecular bone in the latter groups might be ascribed to the patho-morphologic features In osteoarthritis it is assumed that one of the first changes in the subchondral bone is microfractures (Trueta 1963), which might alter the peak transmission force and also the absorption of energy leading to an increased demand on the cartilage which ultimately loses its capacity to handle the forces placed on it and becomes destroyed (Radin et al 1970, Radin 1972)

With the osteolyses of the subchondral bone in rheumatoid arthritis a situation analogous to the osteoarthritis process might arise thus contributing to the cartilage loss, which also can be caused by enzymatic or other chemical reactions It is interesting to note that neither age of patient nor duration of disease seems to influence the hardness To further complete this investigation a histological analysis is under way of the material used for the hardness tests

The tests made on the lateral condyles showed lower hardness in comparison to the medial condyles in the normal group (Figure This is in accordance with the estimations by Kettelkamp & Ch

(1972) that the compression forces on the tibial plateaus are about ten times greater on the medial condyle than on the lateral

SUMMARY

A comparison of the hardness of subchondral, trabecular bone has been carried out in normal bone, and that in osteoarthritis and rheumatoid arthritis It was found that with increasing age the hardness of subchondral bone increased in the normal group irrespective of sex The increase is statistically significant

The hardness of subchondral bone in osteoarthritis and rheumatoid arthritis was significantly lower than in normal bone

There was no difference between osteoarthritis and rheumatoid arthritis

In the normal group the hardness values for the medial condyles were significantly higher than for the lateral condyles

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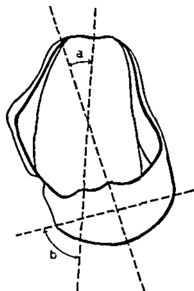


Figure 1 b Drawing of a clubfoot specimen from above Note that in this measuring the medial deviation of the talar neck by using the angle (a) between the axis of the trochlea and the neck The medial deviation of the navicular joint facet is expressed as the angle (b) between the axis of the trochlea and the base line of the facet

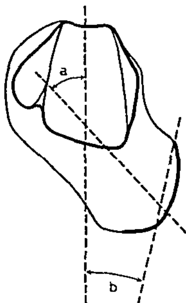


Figure 1 b Drawing of a clubfoot specimen from above Note that in this specimen the actual navicular facet is on the medial plantar side of the head due to the dislocation of the navicular bone Consequently the original facet is reduced both by compression and obliteration The angle (b) is then expressed as the angle between the axis of the trochlea and the baseline of the actual navicular facet

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TALAR DEFORMITY IN CONGENITAL CLUBFEET

An Anatomical and Functional Study with Special Reference to the Ankle Joint Mobility

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Dissection studies performed on foetuses and infants with congenital clubfeet have almost always shown deformities of the foot skeleton. The deformity has been most pronounced in the talus, in the form of a medial and plantar deviation of its neck and head (Adams 1866, Kocher 1879, Parker & Shattock 1884, Scudder 1887, Nichols 1897, Irani & Sherman 1963, Settle 1963, Reimann 1967, Fjeldborg 1971). Other less frequent changes have been a flattening of the trochlea, a reduction of the anterior part of its tibial articular surface as well as its lateral and medial articular facets.

Another fundamental part of the clubfoot deformity is a medial plantar subluxation or luxation of the navicular bone with a consequent deformation of the articular facets of the talar head.

Dissecting two clubfeet with a pronounced deformation of the talus, we found that the deformity itself constituted a hindrance to the dorsiflexion of the foot. This functional hindrance could be forced by cutting tendons and ligaments, but then, instead, there appeared an incongruity in the ankle joint.

In this present study we have given emphasis to the ankle joint mobility which has not been closely examined in previous studies.

MATERIAL

Studies were performed on the feet of a three-day old boy deceased as a consequence of an atrial septal defect and atresia of the aorta. Both feet were fixed in a pronounced equino varus adductus position. No other skeletal deformities were observed. The feet were investigated by arthrography of the talocrural, talonavicular and subtalar joints after which they were dissected. Comparable material was



Figure 3 a The medial aspect of the tibia and talus of a clubfoot specimen The navicular and calcaneus bones have been removed Note the pronounced medial and plantar deviation of the talar head and neck bringing the head in close contact with the tip of the internal malleolus

plantar deviation of the collum was [illegible]0° (normally 27°±8° See Figures 1 a b 2 a b)

The navicular articular surface of the head normally shows a slight medial deviation and the angle between the base of its articular facet and the long axis of the trochlea normally is 74°±10° In our clubfoot preparations the corresponding angle was about 10° (Figure 1 a b) The plantar deviation of the head in the normal material was 70°±7° (Figure 2 a b) In the clubfoot specimens the plantar deviation could not be measured with a satisfactory accuracy because of the simultaneous severe medial deviation The navicular joint surface was reduced to less than half of its normal size by deformation and ob-

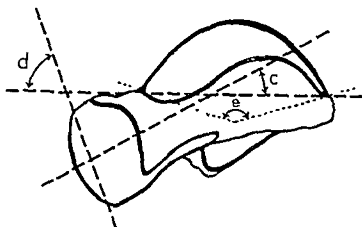


Figure 2 a. Drawing of a normal talus from the medial aspect illustrating the method of measuring the plantar deviation of the neck using the angle (c) between the base line of the trochlea and the axis of the neck The plantar deviation of the navicular joint facet is measured by the angle (d) between the base line of the trochlea and the facet, respectively The way of measuring the central angle (e) is shown

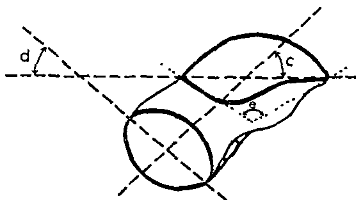


Figure 2 b Drawing of a clubfoot specimen from the medial aspect The plantar deviation (d) is difficult to measure with accuracy in clubfeet with pronounced medial deviation (figure) and impossible to measure if the medial deviation is extreme as in Figure 4 b

obtained by a similar examination of 30 feet without deformities from children 2 days to 18 months of age

RESULTS

The neck of the talus was short and wedgelike in both the preparations, lacking its normal "waist" and the little groove usually found on its dorsal side. The medial deviation of the long axis of the neck related to the long axis of the trochlea was 50° (normal value 28°±10°) The



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Figure 3 b The same specimen after division of the talocrural joint capsule and ligaments In dorsiflexion of the talus the head remained in close contact with the anterior margin of the malleolus Being oblique the latter forced the talar head laterally thus causing a rotational movement of the talus around a vertical axis

literation, and under the influence of the luxated navicular bone a new articular surface was formed on the medial plantar side of the head There was a moderate flattening of the trochlear articular surface A reduction of the anterior part of the trochlear joint surface was also noted and this explains why the central angle (Figure 2 a b) was only 125° (normally 160°) The recesses of the ankle joint were difficult to see directly Arthrograms showed a small back recess, while the front recess seemed to be lacking or extremely compressed (Figure 4 b)

The navicular bone was luxated medially articulating with the medio plantar facet of the talar head Its medial edge was situated close



Figure 3 c Posterior view of the specimen of Figure 3 b Dorsiflexion of the talus has caused a rotational movement of the talus around a vertical axis, in turn causing an incongruence of the talocrural joint

to the internal malleolus, fixed by a very short tibio-navicular ligament It was difficult to determine if this ligament, or the other parts of the deltoid ligament, was thicker than normal.

Notable was the strong fibrous connection between the inside of the internal malleolus and the medial side of the trochlea. These fibres occupied the larger part of the medial surface of the trochlea, leaving only a small area as a normal articulating surface

There were both anterior and posterior subtalar joints, but they were smaller than normal and somewhat deformed. The posterior subtalar joint recess extended backwards between the almost vertical tuber calcanei and the back of the tibia and the fibula.

The tuber calcanei was bent medially like the distal part of the corpus The sustentaculum tali was fairly well preserved The cuboid was in good contact with the articular facet of the calcaneus even if there was a slight rotation and dislocation medially

No abnormal insertions of the tendons were observed The course of the tendons was somewhat changed, but this seemed to be just an adaptation to the skeletal deformities The ligament, too, showed a similar adaptation

Function study

Having removed all the soft tissues except the ligaments, we could with redression obtain only a slight correction of the equinus deformity and the navicular luxation Not even after removal of the calcaneus, navicular and cuboid bones could the talus be dorsiflexed notably This can be explained in three ways

1) The ligaments have lost their elasticity which can depend either on pre- or postmortem changes
2) The joint capsule is tight because of a partial obliteration of the recesses of the talocrural joint
3) the head of the talus deviates medially and protrudes in front of the internal malleolus which like the medially dislocated navicular bone locks the talus in a plantarly flexed position (Figure 3 a)

After division of the capsule and the ligaments of the talocrural joint, we could study how dorsiflexion of the talus was influenced by the talar deformity itself

Dorsiflexion proved to be possible only if

1) the talar head was dislocated laterally losing its contact with the front rand of the medial malleolus This, however, causes a corresponding medial rotation of the back part of the trochlea giving an incongruity in the ankle joint (Figure 3 b and c)
2) the talar head remained in close contact with the oblique front edge of the malleolus during dorsiflexion The talus then naturally dislocates slightly forward, which again gives an incongruity in the talocrural joint

The lack of the dorsal groove of the talar neck also decreases the range of dorsiflexion

Radiographic findings

Arthrograms of the talocrural, talonavicular and subtalar joints enabled a determination of the relationships between the articular sur-



Figure 4 a Arthrogram of the lateral aspect of the talocrural talonavicular and posterior subtalar joints of a normal specimen The needle is left in the talonavicular joint to prevent contrast leakage The trochlear articular surface approximates an arc of a circle The contrast in the anterior recess of the ankle joint outlines the small groove on the dorsal side of the talar neck The dorsal recess is compressed due to the slight dorsiflexion of the joint

faces and an approximation of the shape of the talus The results are in good agreement with the anatomical findings The radiographic method also allows an estimation of the size of the recesses of the joints which can be difficult to evaluate by dissection Arthrograms of the clubfoot specimens showed a partial obliteration of the recesses of the ankle and talonavicular joints (Figure 4 a b)

DISCUSSION

Anatomical findings

Previous investigations (Adams 1854 1855, 1866, Kocher 1879, Parker & Shattock 1884 Scudder 1887, Bissel 1888, Burrell 1893 Nichols



Figure 5 b Arthrogram of the lateral aspect of the talocrural and talonavicular joints of a clubfoot specimen There is some flattening of the trochlea and its articular surface is insignificantly longer than that of the tibia There is a small posterior recess while the anterior recess is absent The trochlea is seen in profile while the talar head is seen en face due to its pronounced medial deviation Note the plantar position of the talar head, which is also positioned behind the frontal border of the trochlea due to the shortness of the talar neck

1897, Bechtol & Mossman 1950, Bernbeck 1950, Irani & Sherman 1963, Settle 1963, Reimann 1967, Fjeldborg 1971) have shown a varying degree of skeletal deformity in clubfeet However, if the deformity varies in its degree, this does not seem to be the case concerning its type Thus, the trochlea of the talus may have an apparently normal form but also be flattened and show a reduction of the front part of its tibial articular surface as well as a reduction of its malleolar articular facets The most pronounced deformity, however, concerns the head and the neck of the talus, which to a varying extent deviate medially and plantarly The more or less deformed navicular bone is subluxated medially-plantarly with a corresponding deformation of the articular facet of the talar head The cuboid is often subluxated but only in exceptional cases fully luxated The calcaneus is bent with its concavity turned medially and the sustentaculum tali is often poorly developed

Our preparations demonstrate a pronounced deformity of the described type, although they do not belong to the most extreme cases described previously in the literature

Concerning the soft tissues, we, as with previous investigators have found only an adaptation to prevailing skeletal deformities, but no changes concerning the insertions of the tendons Histological examination of the soft tissues has not been performed

Thus our dissection study confirms previous observations concerning the skeletal deformities

However, attention can be directed to the fact that in our preparations the articular surface of the trochlea did not extend as far forwards on the neck of the talus as normally noted This means that the articular surface of the trochlea in a sagittal direction extended only slightly beyond the corresponding articular surface of the tibia Another observation, that has not been pointed out by previous investigators, except Kocher (1879), is that either one or both of the recesses of the ankle joint can be obliterated The back recess of the subtalar joint in our preparations formed a false joint between the tuber of the calcaneus and the tibia

Functional study

Tight muscles and ligaments as obstacles to the correction of clubfeet deformity have been carefully examined and discussed by previous authors The skeletal deformity itself, however, as an obstacle to correction and to joint mobility has been a matter of controversy, and this to some extent is due to the variation of the deformities

Our study shows that the talar deformity itself can be a hindrance to dorsiflexion of the foot After cutting the tendons, ligaments and capsule, dorsiflexion was possible only by a rotational or forward movement of the talus, in both cases giving an incongruity in the ankle joint (Figure 3 b, c) Contrary to this finding, Parker & Shattock (1884), as well as Irani & Sherman (1963), have stated that talar deformation does not change the mobility of the ankle joint Fjeldborg (1971) describes an incongruity of the talonavicular and talocalcanear joints after correction but does not mention the ankle joint

Bissel on the other hand wrote in 1888 "In both my specimens it was still impossible to dorsiflex the foot after removal of the muscles and tendons even after division of the whole of the internal ligament without separating some of the articulating surfaces"

A solution of this problem may be as difficult as with the Gordian knot Thus, Nichols as early as 1897 proposed a corrective osteotomy through the talus and the calcaneus However, it is not yet known if this may be done without sometimes causing serious damage to the vascular supply of the talar head and the trochlea

Other anatomical changes of the clubfoot talus, decreasing the ankle joint mobility, are

1) a reduction of the articular surface of the trochlea
2) a flattening of the trochlea
3) lack of the small groove on the dorsal side of the talar neck that fits into the anterior rim of the tibia on dorsiflexion of the foot

A soft tissue change influencing the ankle joint mobility is, as also mentioned by Kocher (1879), a partial or total obliteration of the recesses There is probably no completely satisfactory solution to this latter problem In any case, a posterior capsulotomy will be futile if there is an obliteration of the anterior recess, especially if it is combined with a shortening of the frontal part of the trochlear articular surface

The deformation of the talar head and its articular surfaces explains the difficulty of reposition of the navicular bone as well as the problems of preserving its proper alignment

CONCLUSIONS

1) The skeletal deformities found in our preparations agree with what many previous investigators have found in pronounced pes equinovarus

2) In addition we have found a partial obliteration of the recesses of the ankle joint, a finding which is also confirmed by arthrography in clinical cases This means that not only tight ligaments, but also the capsule itself may constitute a hindrance to dorsiflexion of the talus

3) A reduction of the articular surface of the trochlea, the lack of the dorsal groove of the talar neck and flattening of the trochlea cause limitation of the mobility of the ankle joint

4) If muscles, ligaments and the capsule are eliminated as obstacles for dorsiflexion of the talus, this movement can be performed, but then an incongruity of the talocrural joint arises It should be emphasized that this is true only in cases with a severe talar deformity

5) Due to the deformation of the articular facets of the talar head

the navicular bone may, after reposition, have only a very small supporting area with a consequent great risk for reluxation

8) Obliteration of the recesses of the talonavicular joint has been found and may be a hindrance to reposition of the navicular bone

SUMMARY

Two clubfeet from a new born boy were studied by arthrography and dissection The skeletal deformities agree well with many previous descriptions However, the importance of partial obliteration of the ankle and talonavicular joint recesses as well as the deformation and reduction of the articular surfaces is discussed

A function study shows that when muscles, ligaments and capsule have been eliminated as obstacles to the ankle joint mobility, dorsiflexion will be possible but only at the expense of an incongruity in the ankle joint This is true however only in cases with a pronounced talar deformity The mechanism is discussed

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AN EVALUATION OF THE USE OF STRONTIUM[85] FOR THE ASSESSMENT OF EXPERIMENTAL BONE GRAFTS

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MATERIALS AND METHODS

Animals used in this study were inbred strain AS Wistar Rats. Grafts used were fresh or preserved cancellous bone taken from the ilium of isohistogenic rats. These grafts contained both cortical surfaces and were approximately 6×6 mm square. Fresh grafts were implanted with the contained bone marrow, but were scraped free of adherent muscle and as much periosteum as possible.

Freeze dried grafts were prepared from iliac bone using a Chemlab freeze drying unit and were used after 7–10 days storage at +4° C. Frozen bone was stored at 20° C for up to 3 weeks. Decalcified freeze dried bone was prepared by treating iliac bone with 0.6 N HCl for 2 days in a shaker at +4° C. The bone was then washed six times with sterile 0.9 per cent saline followed by six washes in sterile distilled water. Freeze drying was then carried out and the dried material stored at 4° C for up to 2 weeks. No attempt to remove bone marrow was made with any of these grafts.

Grafts were implanted into a pocket made in the skin of the back of the recipient between the dermis and panniculus carnosis muscle. The skin incisions were closed by means of Michel skin clips. Each rat received from two to four grafts.

Isotope Technique

The isotope used in these experiments was Strontium chloride (Sr^{85}) (Radiochemical Centre SOS IP) which was injected intravenously, or by the intra

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AN EVALUATION OF THE USE OF STRONTIUM^{85} FOR THE ASSESSMENT OF EXPERIMENTAL BONE GRAFTS

MICHAEL W. ELVES

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Studies of bone grafts have been made in experimental animals for reasons ranging from the ascertaining of the cellular changes during osteogenesis, and the nature of osteogenic induction, to the search for the 'ideal' bone bank material. One of the major drawbacks to studies of bone graft behaviour has, however, been the lack of an objective and relatively simple means of assessing the degree of osteogenesis occurring in the graft. This paper reports the evaluation of a method which fulfills these criteria and allows the rapid assessment of large numbers of experimental grafts.

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The isotope used in these experiments was Strontium chloride (Sr^{85}) (Radiochemical Centre SOS 1P) which was injected intravenously or by the intra

peritoneal route, at a dose of 8 μC/100 g *body weight Both routes were equally effective*

For evaluation of the grafts the rats were killed with chloroform after removal of 1 ml blood Bone grafts were recovered, dissected free of connective tissue weighed and fixed in neutral formol saline Both ilia were removed from each recipient and weighed A section of cortical bone from one femur was also taken and weighed after the marrow had been washed out Blood samples grafts in fixative and the cancellous and cortical bone samples were then placed in a Nuclear Enterprises NE 8312 Auto γ and β counter and the activity of the contained Sr^{85} counted Background readings were subtracted from the total counts given by the bone and the grafts and these figures were then adjusted to give counts per minute per milligram of tissue An osteogenic index could then be calculated as follows

$$\frac{\text{ct/min/mg of graft}}{\text{ct/min/mg of ilium}}$$

Grafts, once they had been counted were then decalcified and processed for histological examination so that assessment made by use of the isotope might be checked microscopically

RESULTS

Experiment 1—Time between administration of isotope and sacrifice Uptake of bone seeking isotopes occurs by a number of processes such as *simple exchange and diffusion, or active incorporation* into bone mineral during new bone formation (Bauer et al 1958) Only the latter process is, however, of any value in assessing osteogenic activity of bone Experiments have therefore been carried out in order to determine the optimal interval between isotope administration and examination so that the Sr^{85} measured would mainly be that incorporated into bone mineral and not merely present by virtue of exchange

Seven groups, each consisting of four 3-month old rats, were injected i v with Sr^{85} Groups were killed after 4, 24 48, 72 hours and 4, 5 and 8 days Radioactivity present in each of the ilia was estimated Each piece of bone was then placed in 20 ml of a 1 per cent solution of $CaCl_2$ in 0 9 per cent saline and agitated continuously for 24 hours at + 4° C The bone was blotted dry and its radioactivity recounted The bones were then returned to fresh $CaCl_2$ solution for a *further 24 hours* agitation The Sr^{85} in the bones was then counted again Thus each piece of bone was eluted for 48 hours Preliminary studies had indicated that by 48 hours a plateau has been reached in the elution

Table 1 The uptake and incorporation of Strontium85 in the skeleton of rats at various times after injection of the isotope

Time after injection of Strontium85	No of samples	Uptake by ilium (ct/min/mg) (±S E)	% isotope remaining after elution* (±S E)	Incorporation by ilium† (ct/min/mg)
4 hours	6	717 2 (±16 35)	57 0 (±0 67)	509 9
24 hours	8	816 6 (±27 80)	78 6 (±0 70)	697 4
48 hours	8	832 4 (±18 64)	85 4 (±0 34)	740 0
72 hours	8	853 4 (±15 10)	91 0 (±0 61)	810 3
96 hours	8	707 6 (±18 92)	92 4 (±0 51)	680 0
5 days	6	719 6 (±31 39)	95 0 (±0 30)	692 2
8 days	8	610 1 (±13 10)	–	–

* Per cent of original Sr85 which could be eluted over a period of 48 hours *in vitro* by CaCl

† These data are derived from the uptake shown in column 3 corrected by per cent shown in column 4

curve and a negligible amount of radioactivity is elutable during the third 24 hour period (48–72 h)

Strontium85 was rapidly taken up *in vivo* by the iliac bone during *the first 4 hours after injection (Table 1, col 3)*, and uptake continued to increase over the next 68 hours The radioactivity in the bone then fell

When the bones were eluted with $CaCl_2$ solution, the Sr85 was readily lost from those removed from rats killed 4 hours after injection and almost 50 per cent of the total activity was eluted (Table 1, col 4) It was not until 3 4 days after injection that the amount of Sr85 which was firmly bound in the bone and consequently not eluted reached 90 per cent of the total radioactivity It can be assumed that this "non-elutable strontium mainly represents that which *had been incorpo*rated during new bone formation The uptake data can be corrected by the elution data to give a value for strontium incorporation due to accretion in the skeleton (Table 1, col 4) The peak of incorporated strontium was found to occur at 3 days Thereafter a fall in Sr85 content occurred which was presumably due to resorption On the basis of these data 3½ days was chosen as the interval between administration of the strontium and sacrifice in later studies

Experiment 2

The previous experiment indicated that the readily exchangeable strontium formed only a small percentage of the total radioactivity in

Table 2 The uptake of Strontium[85] and histological osteogenesis in autografts of fresh, preserved and decalcified bone grafts 4 weeks after grafting

Type of graft	No of rats	Strontium index (± S E)	Histological evidence of new bone
Fresh	12	1 45 (±0 14)	++++
Frozen	12	0 19 (±0 01)	—
Freeze dried	12	0 18 (±0 01)	—
Decalcified	12	0 07 (0 002)	±

Table 3 An illustration of the effect of recipient age on Strontium[85] uptake by graft and skeleton, and on the osteogenic index

Age of recipient at start of experiment	Sr[85] activity (ct/min/mg) in (± S E) Graft 1 wk	Graft 2 wks	Graft 3 wks	Ilium 1 wk	Ilium 2 wks	Ilium 3 wks	Osteogenic index (± S E) 1 wk	2 wks	3 wks
7 months	612 6 (±43 7)	1895 9 (±112 6)	1295 4 (±115 8)	523 6 (±16 8)	429 0 (±18 3)	413 2 (±19 2)	1 16 (±0 08)	4 45 (±0 4)	3 13 (±0 2)
3 months	404 8 (±43 2)	1367 8 (±130 5)	1204 [illegible] (±69 0)	783 8 (±14 7)	673 5 (±16 4)	630 4 (±16 4)	0 52 (±0 05)	2 04 (±0 2)	1 84 (±0 11)

a



b

Figure 1 Photomicrographs showing a) cellular population and new bone formation in fresh iliac bone isografts after 4 weeks and b) typical appearance of a graft of frozen bone. NB — New Bone CT — connective tissue G — Old graft (H & E + Alcian Blue × 250)

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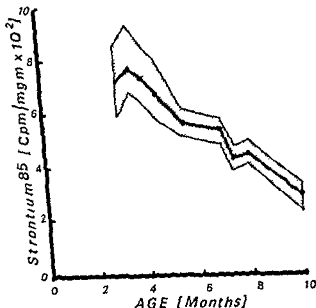


Figure 2 The mean incorporation of Sr85 into iliac bone of rats of different ages Stippled region = standard deviation

new bone formation *in vivo* It has in fact been used by a number of workers for the assessment of malignancies affecting the skeleton (Bauer & Wendeberg 1959, Gerson et al 1972, Kofman et al 1963, Parsons et al 1969), and for the study of fracture repair and inflammatory and reactive lesions in the skeleton (Bauer & Wendeberg 1959 Dymling & Wendeberg 1961)

Radioisotopes of strontium have been widely used in studies of calcium metabolism on the assumption that strontium and calcium follow similar metabolic pathways (Bauer et al 1955, Samachson & Spencer 1961) There are, however, some differences between the handling of these two elements in the body Thus calcium is better absorbed than strontium from the gut and is also excreted more slowly (Harrison et al 1966) The former difference is irrelevant in the context of the present study in which the strontium is administered parenterally

Strontium is taken up into the skeleton in two ways The first is by diffusion and simple exchange with calcium in mature bone, while the second is by active incorporation into the mineral of newly formed bone (Bauer et al 1958) In studies of osteogenic sarcomata it has been

the bone when a period of 3½ days was allowed to elapse between injection of isotope and the estimation This experiment does not, however, indicate the extent of exchangeable strontium held in the deeper parts of the bone "Deep exchange" may be a slow process In order to estimate the importance of slow deep exchange, rats were grafted with living bone autografts, freeze-dried and frozen autografts and decalcified autografts After 4 weeks the experiment was terminated, the isotope having been injected 3½ days before sacrifice Sr^{85} uptake was estimated for each graft and expressed relative to skeletal activity, as an osteogenic index

The results are shown in Table 2 Histologically new bone was abundant in the fresh autografts (Figure 1 a) whilst no new bone was seen in either frozen or freeze-dried grafts (Figure 1 b) Decalcified grafts contained a very small amount of new bone The index of strontium uptake was high in the case of the fresh grafts but low in the case of calcium-free grafts Despite the absence of new bone formation in frozen and freeze-dried grafts there was some strontium retention This retention, which may be due to the slow "deep exchange" process, however, was small and represented only 18–19 per cent of the skeletal uptake The fact that negligible strontium was retained in the calcium-free grafts also suggests that the "deep exchange" process does occur in intact grafts but its magnitude is not great

Experiment 3—Effect of age of recipient on Osteogenic Index

An important consideration with this technique was found to be the age of the recipient animal It was found that incorporation of strontium by the rat skeleton decreases sharply with increasing age after 4½ months (Figure 2) This phenomenon may introduce two artefacts into the quantitation of uptake by grafts Firstly, as the older host will take up less strontium into the skeleton there will be more isotope available for uptake by the graft this may lead to small differences in graft uptake in young and old recipients Secondly, as the osteogenic index is related to the skeletal rate of new bone formation the ratio calculated in old hosts will be considerably higher than in young hosts These effects are illustrated in Table 3

DISCUSSION

Strontium^{85}, being a γ-emitting isotope is amenable to external counting and is, therefore, a potentially useful tracer for the assessment of

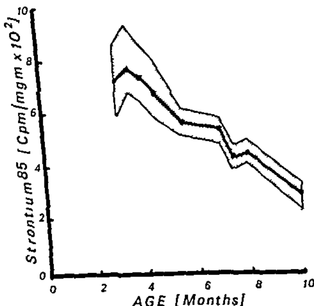


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sistent with their high strontium85 uptake All of these isografts showed a profusion of new bone in the intertrabecular spaces and all but two gave Sr^{85} uptake indices considerably in excess of 1 0 In contrast no preserved graft contained any histologically detectable new bone and none gave uptake index in excess of 0 26 Uptake levels in these grafts, however, never fell below an index of 0 13 Most freeze-dried decalcified grafts took up much lower amounts of strontium and most contained only very small amounts of new bone These observations indicate that the strontium uptake by the frozen and freeze dried grafts measured after 3½ days, was due to remaining passively exchanged isotope rather than active incorporation As this passively exchanged isotope is retained, it may be suggested that isotope reaching the deep mineral of the graft is removed again by exchange much more slowly than that exchanged into the more superficial mineral The elution experiment described above also suggests that 3–4 days after injection of isotope about 6 per cent of the total Sr^{85} activity in the bone can still be ascribable to isotope in the exchange pool From the above data it is clear that the amount of strontium retained in these grafts by this deep exchange is small in comparison to the amount incorporated during osteogenesis in fresh grafts However, it should be borne in mind when evaluating grafts with low osteogenesis, and an index of below 0 30 should be regarded as negative for calcium containing grafts

The association of high levels of strontium uptake with grafts in which considerable new bone is present is strong evidence that the greatest part of the strontium detected in these grafts is in fact in the newly formed bone As Sr^{85} is a gamma emitting isotope it is unfortunately not possible to obtain direct evidence of this association by means of high resolution autoradiography The gross forms of autoradiography employed by others using this isotope are of no value at the histological level (Gerson et al 1972)

Methods previously used for the assessment of new bone formation in bone grafts require manipulation of the graft to render it suitable for either histological examination or biochemical analysis The histological methods have been adapted to afford a crude score of osteogenesis (Burwell 1966 Chalmers et al 1960, Salama et al 1973) They are however time consuming and tedious because in order to be truly representative they require the cutting of serial sections, furthermore they are subjective and at best only semiquantitative Fischein & Urist (1972) have used the biochemical determination of alkaline

shown that high levels of uptake Sr^{85} generally occurred in areas of new bone formation and not in areas of established bone (Charkes et al 1966, Gerson et al 1972).

In order to measure new bone formation it is essential to allow a sufficient length of time to elapse between administration of the isotope and the assessment of radioactivity in order to enable the passively exchanged isotope to become diluted. This leaves the incorporated isotope as the *major countable activity* The first experiment reported above showed that this time interval, in the rat, should be three to four days Bauer & Wendeberg (1959), using human subjects, found a higher ratio of counts in areas of new bone formation, compared with the normal contralateral bone, when the counts were made 4 or 7 days after injection of isotope than when the assessment was made two days after injection (see their case 4) Sr^{85} has been used by Goldberg & Lance (1972) in a study of bone grafts in rabbits but only 48 hours was allowed to elapse between administration of the isotope and sacrifice Thus in this study it is likely that a significant amount of passively exchanged isotope was still present in the graft

The method described above affords a relatively simple and objective means of assessing the state of new bone formation in bone grafts The Osteogenic Index used in this paper was devised in order to relate the strontium bound in the graft to the rate of new bone formation in the general skeleton on a weight basis By relating the isotope uptake of the graft to that by the host's skeleton the osteogenic index therefore enables a comparison to be made between osteogenesis at the site of the graft and that in the host skeleton It is also possible to correct for any discrepancies in the injected dose between individuals The technique would also be suitable for the monitoring of bone graft progress in the human subject using external counting or gamma scanning techniques

The above data emphasise that in designing experiments careful consideration must be given to the age of the recipient This is particularly important for long-term experiments Skeletal osteogenesis in rats declines rapidly over the age of 5 months to 10 months Animals between these ages should therefore be avoided as far as possible, the grafts if placed in them should not be compared with those in younger hosts, as considerably higher osteogenic indices can be found in the former

The histological appearance of the fresh bone grafts was con-

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phosphatase as an index of osteogenesis This technique is however also lengthy and requires a homogenate to be prepared from the graft which is thus not available for a histological check Furthermore it is possible that other cells within the graft, which are not involved in osteogenesis may interfere For example neutrophil granulocytes in the inflammatory *state usually contain elevated levels of alkaline* phosphatase (Leonard *et al* 1958, Wulf 1963)

SUMMARY

A method is described which permits a simple objective and quantitative assessment of new bone formation in experimental bone grafts This method is based upon the incorporation of the γ emitting isotope strontium^{85}, into new bone within a graft This isotope is easily counted using a crystal scintillation system

Various factors have been found to be important for the application of this method It has been found that the interval between administration of isotope and assessment of the radioactivity within the graft is important in order to avoid the masking of incorporation during new bone formation by the uptake of strontium into old bone by exchange processes Comparison of strontium uptake in grafts of dead bone lacking osteogenesis with that in decalcified material indicates the existence of a slow exchange process probably involving the deep mineral of the graft This slow exchange however would account for only a small amount of the strontium retained in fresh grafts in which new bone formation is abundant The age of the recipients must also be standardized for comparative studies

This method as well as being useful for quantitative studies of bone grafts in experimental animals may also have an application for the clinical assessment of bone grafts in the human

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CORACOCLAVICULAR WIRING FOR ACROMIOCLAVICULAR JOINT DISLOCATION

A Ten Year Follow-up Study

ARVID EJESKÄR

Accepted 7 ii 74

At the Department of Orthopedic Surgery I (formerly Department of Extremity Surgery), Sahlgren Hospital, Goteborg, the standard method of treatment for acute acromioclavicular dislocations has been fixation of the clavicle to the coracoid with a single loop of wire of stainless steel Among the long-term results (mean time of follow-up greater than 1 year) which have been published (Arner et al 1957, Bergh 1945, Hackstock and Jacobs & Wade 1966, Lazcano et al 1961, Millbourn 1949/50, Scholze & Ludwig 1970, and Wilson & Prothero 1967), Bergh reported the results of a series of 6 patients followed from 3 months to 2½ years Arner et al reported 14 cases operated with a slightly modified technique using a double loop of wire This study was undertaken in order to report the results of a larger series of patients consistently treated with the above-mentioned method and with a longer period of observation

METHOD

With the patient under general anaesthesia an incision is made from the acromio clavicular joint along the anterior margin of the clavicle and down into the delto pectoral sulcus to the tip of the coracoid The clavicular portion of the deltoid is divided near its origin In the majority of cases (39 out of 65) the acromioclavicular joint was also exposed and interposing tissue was excised A wire of stainless steel 0 9–1 0 mm in diameter is brought around the coracoid process and the clavicle at a point directly above the coracoid This is important in order to achieve an anatomi cal position in the acromioclavicular joint (Figure 1) After reduction of the dis location, the wire is tightened sufficiently to keep the lateral end of the clavicle level with the acromion The position is checked with a peroperative roentgenogram In one instance transfixation of the acromioclavicular joint was also included

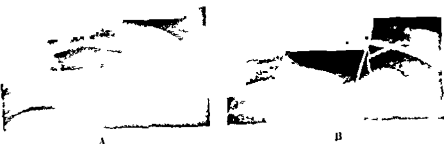


Figure 1 *A dislocation in the acromioclavicular joint which has been operatively treated* *The wire is placed too far medially permitting the joint to dislocate (A)* *The same patient after correction of the position of the wire (B)*

MATERIAL

During the period 1959 to 1965, a series of 65 patients were treated by the method described above 60 were men and 5 women The mean age of the patients was 39 years with a range from 15 to 64 years The right shoulder was injured in 30 instances and the left in 35

The mechanism of injury in 33 patients was a variety of traffic accidents and in 30 instances a fall upon the shoulder One patient was struck on the shoulder by a falling object and one was pressed between heavy metal sheets The time between injury and operation was less than one week in 52 instances and less than one month in all patients Although all patients were considered to have a complete dislocation at the time of treatment, the follow up revealed that the diagnostic criteria had not always been strict A re-assessment based on the initial roentgenograms and the operative report was performed The criteria for a complete dislocation were either an upward displacement of the lateral end of the clavicle in relation to the acromion equal to or greater than the thickness of the clavicle and/or a total rupture of the coracoclavicular ligaments as observed at operation With this definition 51 cases were assessed as having a complete dislocation and 14 patients as having subluxation of the acromioclavicular joint

Postoperatively the shoulder was immobilized by fixation of the arm to the body for an average time of 26 days The time of immobilization varied however, from 0 to 51 days The wire was extracted (6 weeks to 5 years postoperatively) in 28 instances in some cases because of pain but in other patients as a routine procedure to prevent the wire from creating problems In two cases resection of the lateral end of the clavicle was done because of persistent pain

Follow-up

At the time of follow up (1971) 8 patients had died (12 per cent) and 3 were not available for examination (5 per cent) The remaining 54 patients (83 per cent) were all personally examined 6–12 years after injury (average 9 6 years) The patients were questioned with regard to residual pain and weakness and the degree of

deformity and tenderness on palpation was noted Shoulder motion was measured bilaterally in abduction, elevation and rotation and muscle strength was tested in the same directions by means of a Zadig Dynamometer (Zadig 1963) Roentgenograms of both acromioclavicular joints were taken on all patients

When evaluating the muscle strength, the difference between the right and left shoulder in percentage of the force in the left arm was calculated The number of injured right and left shoulders were almost equal and as only four persons were left handed statistical assessment between the two groups of right handed persons could be done A reduction in strength of more than M ± 2 SD was called 'reduced muscle strength"

The results of the follow up were divided into four groups based mainly on the frequency and intensity of pain but also to a certain extent on the degree of limitation in shoulder motion and deformity The groups were defined as follows

Excellent Patients free of symptoms with a normal range of movement and no deformity *Good* Patients who were without symptoms or complained only of tenderness on palpation and/or had a restriction of motion up to 5° in one or two directions and/or a deformity of less than 10 mm, and/or a painless reduced muscle strength" *Acceptable* Patients occasionally or up to once a week having slight to moderate pain not interfering with activities or sleep and/or having a restriction of movement less than 10° in one or several directions *Poor* Patients complaining of pain more often and above all of an intensity which disturbed night rest or caused reduced working capacity

Table 1 Complications

Suture granulomas	2
Superficial infections	2
Deep infections	1
Haematoma	2
Early redislocation	3
Rigidity of the shoulder requiring mobilization under anaesthesia	1
Penetration of piece of the wire loop into the glenohumeral joint	1
Total number	12

RESULTS

Complications

There were 12 complications (18 per cent) (see Table 1) Two cases with suture granulomas and two with superficial infections healed without problems One deep infection including osteitis of the clavicle healed in 3 months following extraction of the wire One haematoma which appeared some hours after an extensive exploration for a broken

wire required evacuation One small haematoma was aspirated One patient required mobilization of the shoulder joint under anaesthesia Faulty operative technique resulted in early redislocations in two cases and a new trauma was the possible cause in another one All these three patients were reoperated with uneventful recoveries

Migration of the wire occurred in one case A portion of the wire was extracted from the glenohumeral joint 2½ years after removal of the main part

Results of the Clinical Examination at Follow up

The results of the follow up were 16 excellent (1 subluxation, 15 dislocations), 19 good (5 and 14 respectively), 15 acceptable (4 and 11 respectively) and 4 poor (1 and 3 respectively)

Of those patients with a good result, 5 complained of tenderness on palpation 7 showed a deformity of 5 mm and one of 10 mm, 7 had a limitation of shoulder motion of 5° Among those with an acceptable result 3 were tender on palpation 3 had a deformity of 5 mm 5 patients had restriction of shoulder motion of 5° and 4 up to 10° In the poor group 2 patients had a deformity of 5 mm 2 had limitation of shoulder motion one up to 5° and one up to 10°

The assessment of the muscle force measurements revealed a slight tendency towards diminished power on elevation and abduction but the values were not statistically significant However reduced muscle strength in these two directions was found in a total of 6 patients, 4 of these classified as poor had pain in their shoulder on testing but the other 2 who were considered as good, had painless shoulders and a reduction of force in only one direction

Difficulties arose with evaluation of the findings in 3 cases One patient had an operation performed for recurrent dislocations of the ipsilateral glenohumeral joint some years after the injury to the acromioclavicular joint At the follow up he had slight discomfort from the shoulder but showed a reduction in elevation and outward rotation of 25° and 15° respectively He was therefore classified as acceptable Another patient had symptoms and signs of a rotator cuff lesion without any complaints attributable to the acromioclavicular joint He was also considered to have an acceptable result A third patient classified as having a poor result had a history of cervical spondylosis

The results at follow up could not be correlated significantly with arthrotomy at operation but the frequency of arthrotomy was some-

deformity and tenderness on palpation was noted. Shoulder motion was measured bilaterally in abduction, elevation and rotation and muscle strength was tested in the same directions by means of a Zadig Dynamometer (Zadig 1963). Roentgenograms of both acromioclavicular joints were taken on all patients.

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Figure 3 A dislocation of the acromioclavicular joint where the evolution of remodelling of the joint can be seen A Dislocated joint B Peroperative picture C 14 months after surgery D At follow up 7 years postoperatively

characteristics of osteoarthritis A prerequisite for this remodelling is probably some degree of upward displacement

DISCUSSION

As stated above 50 out of 54 patients were considered to have an acceptable result or better If the two cases in whom resection of the lateral end of the clavicle are included in the poor results 48 out of 54 cases (90 per cent) are acceptable or better This is in accordance with the results found in the literature For instance Arner et al (1957) found poor results in 3 out of 39 conservatively treated patients and in 3 out of 16 treated operatively Jacobs & Wade (1966) stated that 7/35 patients treated operatively were dissatisfied versus 5/43 with conservative treatment In these two series the proportion of subluxations was much higher (23/56 and 35/78 respectively) than in this series (11/54) Hackstock (1966) wrote that 2/56 had pain and 3/56 demonstrated restricted abduction without classifying the results using

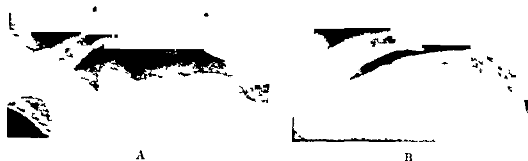


Figure 2 Patient with osteolysis in the "normal" shoulder Roentgenogram taken at the time of the accident (A) Roentgenogram taken at follow up 12 years later (B)

what higher in the patients with excellent and good results than in the other two groups The duration of fixation was somewhat shorter in the patients with a poor end result but the variation within each group was too great and the groups themselves too small to allow any definite conclusions Those who still had the wire loop *in situ* had slightly better end results than the others

Results of the Roentgenological Examination at Follow-up

In 34 patients an anatomical position was found, whereas in 17 some upward displacement of the clavicle was found including two cases with unreduced dislocations in spite of operation Three patients showed some downward displacement

When comparing these roentgenograms with those taken immediately postoperatively a clear tendency for a slight upward shift of the clavicle during the healing period was revealed No correlation between the late roentgenological position of the clavicle and the functional result could, however, be found

Resorption of bone at the distal end of the clavicle of the type called "posttraumatic osteolysis" (Allen 1967, Jacobs 1964, Madsen 1963 and Ståhl 1952/54) was present in one patient However, the same process was found in the uninjured shoulder of three other patients (Figure 2)

Six patients, all over 53 years of age, had degenerative changes in the acromioclavicular joint and all but one had bilateral changes of equal degree Half of them were free of symptoms including the one with unilateral osteoarthritis of slight degree on the injured side

In 8 cases a transformation of the joint from a so-called "vertical type" to a more or less "horizontal" one could be seen (Figure 3) This phenomenon, earlier described by Arner et al (1957), has none of the

acromioclavicular joint, or with the instability following a non-treated or insufficiently treated dislocation

When trying to explain the poor results most authors mention post-traumatic osteoarthritis The frequency of degenerative changes following injuries to the acromioclavicular joint as reported in the literature varies from 19 100 per cent in the operatively treated patients and 11 60 per cent after conservative treatment (Table 2)

Table 2 Frequency of roentgenological osteoarthritis after injury to the acromioclavicular joint

Author	Operative treatment	Conservative treatment
Arnér et al (1957)	60% (10/17)	50 % (20/39)
Hackstock (1966)	54% (30/56)	—
Jacobs & Wade (1966)	35% (12/35)	11% (5/43)
Lazcano et al (1961)	35% (7/20)	—
Millbourn (1949 50)	100% (4/ 4)	60% (6/10)
Wilson & Prothero (1967)	19% (6/32)	—
Own series	11% (6 54)	—)

However only Millbourn (1949/50) makes the comparison between the uninjured and the injured shoulders and he found 6 out of 10 patients to have bilateral arthrosis of equal degree Arnér et al (1957) and Wilson & Prothero (1967) reported that only half of the degenerative changes on the roentgenograms were symptomatic and Jacobs & Wade (1966) found the corresponding figure to be 60 per cent

In this study an incidence of 11 per cent was found The changes were found in middle aged persons of whom all but one had bilateral arthrosis of equal degree Half of these patients had symptoms Therefore it is believed that the roentgenological findings in this series of patients cannot be ascribed to the injury to the joint but instead represent an idiopathic osteoarthritis which according to Lindholm (1936) is a common finding in old age

The cause of the bad results in the four patients is, in spite of this evaluation of treatment still obscure One explanation could be the different degree of injury to the nerve supply of the acromioclavicular joint This joint is innervated by the supraclavicular and suprascapular nerves The latter one passes through the notch on the superior border of the scapula At the moment of injury the nerve can be stretched or torn when the scapula and the clavicle separate

a total evaluation of each patient Lazcano et al (1961) reported a series of 73 patients treated with a large number of different methods Each uniformly treated group of patients was as small as the total number of patients reported by Bergh (1945), Millbourn (1949/50) and Scholze & Ludwig (1970) The same holds also for the number of cases reported by Wilson & Prothero (1967) These series are too small to allow a comparison.

The lack of a generally accepted criterion for a complete dislocation versus subluxation also makes comparison between different reports more difficult However, Fischetti (1962) stated that it is possible to differentiate between the two degrees of injury using arthrography of the acromioclavicular joint No confirmation of this finding is found in the literature

Searching for important points in the treatment it was not possible to prove a definite correlation between arthrotomy and the end result However, it was quite clear that arthrotomy ensured a better reduction of the clavicle as in 4 out of 5 cases with great postoperative residual displacement (3 cases reoperated, 2 not corrected) arthrotomy was not done In the last case another technical error caused early redislocation The importance of arthrotomy has previously been stressed above all by Horn (1954) and Kennedy (1954)

The wire can be left without causing much discomfort The only complaint that could be attributed to the wire was slight local tenderness in six patients The one exception is the patient in whom a piece of wire migrated into the gleno-humeral joint

The findings of a slight tendency towards diminished power in elevation and abduction has not previously been reported, but only Hackstock (1966) and Lazcano et al (1961) have tested the strength and then only manually

In the literature, posttraumatic osteolysis is reported to occur after varying degrees of injury to the acromioclavicular joint, but some patients have denied previous trauma The interval between the accident and the symptoms has varied from some weeks up to more than 10 years The injuries have initially either been neglected by the patients or treated conservatively In this material 3 out of 4 cases with posttraumatic osteolysis have the process localized to their undislocated clavicle Only one of them had had a trauma to that shoulder The roentgenograms taken immediately after the accident were normal Therefore I believe that posttraumatic osteolysis, if posttraumatic at all, is more correlated with minor traumas such as distorsions of the

acromioclavicular joint, or with the instability following a non treated or insufficiently treated dislocation

When trying to explain the poor results most authors mention post-traumatic osteoarthritis The frequency of degenerative changes following injuries to the acromioclavicular joint as reported in the literature varies from 19 100 per cent in the operatively treated patients and 11 60 per cent after conservative treatment (Table 2)

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CONCLUSIONS

This study shows that our results with coracoclavicular wiring are equal to or better than those previously published. The risk of post-traumatic osteoarthritis with this treatment is minimal. Arthrotomy should be done in every case as it ensures a good reduction and it may also be of value for the final result. Furthermore the need for better criteria for the definition of subluxation versus dislocation is apparent.

SUMMARY

An analysis was performed of 65 acromioclavicular joint injuries consistently treated with fixation of the clavicle to the coracoid with a wire loop. 8 patients were dead whereas 3 could not be reached. The remaining 54, 43 dislocations and 11 subluxations, have been clinically and roentgenologically evaluated 9.6 years (average) after the injury.

a. The result is acceptable or better in 48/54 patients (90 per cent) which is equal to or better than previously published figures.
b. Arthrotomy is important to secure a good reduction and is probably also of value for the end result.
c. No definite case of roentgenological posttraumatic arthrosis has been found.

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OSTEOMYELITIS OF THE CLAVICLE

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Accepted 18 ix 73

Osteomyelitis of the clavicle is rare. It is important to study the clinical features, pattern of bone involvement, and radiological manifestations of this disease in the clavicle Sometimes it can be confused with tuberculous disease of the clavicle or with tubercular sinuses secondary to supraclavicular tuberculous lymphadenitis.

D'Abreu (1933) and Gray (1944) each reported a single case of clavicular regeneration after excision for osteomyelitis in a 14 and a 12-year-old male patient, respectively Echstein (1951) and De Belder (1955) separately each described a case of staphylococcal infection of the clavicle one during scarlet fever and the other due to direct spread from infective cervical glands Wakatsuki et al (1963) reported a case of the superior vena cava syndrome presumed to have resulted from postoperative disorder of bilateral clavicular osteomyelitis

MATERIALS AND METHODS

Twelve cases of osteomyelitis of the clavicle who attended Willingdon Hospital New Delhi and the H P Medical College Simla between 1966 and 1972 were studied

A detailed history was recorded and a detailed clinical examination of the patients was carried out and they were investigated roentgenographically Culture and sensitivity testing of the discharge or aspirate was also performed Serological tests were carried out to exclude syphilis which at one time was considered to be a common type of infection involving the clavicle Histopathological examination was made of the material in operated cases

Observations

The ages of the patients varied from 6 weeks to 22 years, with an average of 12 7 years Eight patients were males and four were females The left clavicle was involved in seven and the right clavicle in five patients

Local presenting symptoms were discharging sinus in ten cases hot red soft cystic tender swelling in one and painful thickened irregular clavicle in another



Figure 1a X ray photograph showing expansion of the entire clavicle on the left side



Figure 1b X ray photograph of the same patient 3 years after excision of the entire clavicle showing complete regeneration of the clavicle



Figure 2 a Clinical photograph showing the medial portion of the clavicle projecting out through a sinus



Figure 2 b X ray photograph of the same patient showing moth eaten appearance in the lateral third



Figure 2 c Resected specimen of the same clavicle

The patients presented for treatment after a period of 3 to 52 weeks an average of 14 8 weeks from the onset of the first symptom *Multifocal osteomyelitic lesions* were seen in five cases presenting as osteomyelitis ulna in one case bilateral osteomyelitis femur with septic arthritis in the left hip (one case), osteomyelitis femur in two cases and in one case osteomyelitis femur with septic arthritis of the hip and knee joints

Roentgenograms showed irregular expansion destruction and periosteal reaction in eight cases (Figure 1 a b) moth eaten appearance in the lateral third of the clavicle and dislocation of the sternoclavicular joint in one case (Figure 2 a b) periosteal reaction with soft tissue swelling in two cases and double fracture with sequestration of the middle segment in another case (Figure 2 c)

Staphylococcus aureus was the causative organism in eleven cases and was sensitive to one or other of the antibiotics The antibiotics subjected to the sensitivity test were penicillin streptomycine Chloramphenicol tetracycline erythromycine and Rovamycine Culture was not performed in one case

Excision of the clavicle under cover of appropriate antibiotics was carried out in eight cases In another case the sinuses healed after extrusion of the sequestrum itself Two patients would not agree to operation

Histopathological examination confirmed the clinical diagnosis in all the eight operated cases

DISCUSSION

Early diagnosis of osteomyelitis of the clavicle is usually not made, because local symptoms and signs are often considered due to trauma and general symptoms and signs of toxaemia are considered due to



Figure 2 a Clinical photograph showing the medial portion of the clavicle projecting out through a sinus.

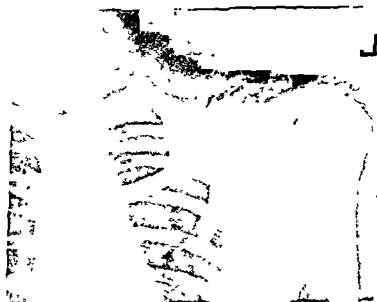


Figure 2 b X-ray photograph of the same patient showing moth-eaten appearance in the lateral third

1 Osteomyelitis of the clavicle was seen mostly in males at the growing age (except in one case)
2 The lesion was diffuse and diaphyseal, involving the whole or an appreciable part of the clavicle
3 Roentgenograms showed extensive bone destruction, diffuse bony thickening and occasional sequestrum formation
4 In chronic lesions with diffuse thickening of the clavicle, the choice of treatment was total claviclectomy

ACKNOWLEDGEMENT

The authors would like to thank Dr N D Agarwal Professor of Orthopaedic Surgery Government Medical College Patiala and Dr Das Gupta, Pathologist Willingdon Hospital New Delhi for their constructive suggestions on the writing of this paper

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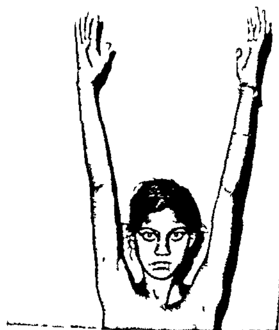
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Figure 2 d. Post-operative clinical photograph of the same patient



associated sore throat or to skin infection, which are the primary source of infection of the bones Multifocal osteomyelitis is considered to be commonly caused by streptococcus haemolyticus because of its spreading character, in all cases of our series it was due to staphylococcus aureus

Simple sequestrectomy and saucerization may be inadequate for osteomyelitis clavicle because of its diffused involvement Complete removal of the clavicle is said to lead to drooping of the shoulder and functional disability of the shoulder girdle However, in our series there was no drooping of the shoulder and all patients could do over-head abduction a few days after the operation for excision of the clavicle (Figure 2 d) There was partial to complete regeneration of the clavicle from the periosteal tube in all the eight cases, depending upon the period since excision An immediate post-operative complaint was loss of sensation in the distribution of the supraclavicular nerves, but this disappeared in the course of time

SUMMARY AND CONCLUSIONS

A detailed study of ten cases of osteomyelitis of the clavicle was carried out Two cases would not agree to operation and were lost to follow up The following points emerged from this study



Figure 1 Roentgenogram showing a destructive lesion over the acromial end of the left clavicle

age distribution was 23 7 years The lesion occurred on the left side in six cases on the right side in four cases and bilaterally in two cases Of the two bilateral lesions one had a lesion at both acromial and the other at both sternal ends Out of fourteen clavicles including the two bilateral cases in eight the sternal ends and in five the acromial ends of the clavicle were involved However the lesion was diaphyseal in one case From these observations it is clear that the lesion starts and remains localized mostly in the metaphyseal region in tuberculosis of the clavicle (Figure 1) Sirkin & Baumgartner (1936) were, however of the opinion that it starts in the diaphysis and then can extend to any part of the bone

Locally presenting symptoms were chronic discharging sinuses in five cases gradually increasing painful swelling in six cases and depressed thin scars adherent to the underlying clavicle on both sides in one patient General symptoms of tuberculous toxaemia such as lassitude loss of weight poor appetite and low grade temperature were seen in five cases only These patients also had associated tuberculous lesions in the spine and had had no previous anti TB therapy

Associated skeletal tuberculosis was seen in eight out of twelve

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TUBERCULOUS OSTEOMYELITIS OF THE CLAVICLE

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Tuberculosis has become a rare disease in advanced countries due to the general improvement of health and medial care, but it still is quite common in India

Bone and joint tuberculosis constituted about 0 57 and 3 per cent, respectively, of all orthopaedic cases attending Willingdon Hospital, New Delhi, and the H P Medical College, Simla, in the last five years Of the total of 669 cases of skeletal tuberculosis, twelve cases of tuberculous lesion of the clavicle were found

There is little information in the medical literature regarding the incidence of tuberculous lesions of the clavicle Sirkin & Baumgartner (1936) reviewed 30 cases of tuberculosis of the clavicle reported in the literature since 1882 (the date of discovery of the tubercular bacillus by Koch) Among 230 consecutive cases of skeletal tuberculosis, Lafond (1958) reported only one involving the clavicle Jensen (1959) published 5 cases of tuberculous osteomyelitis of the clavicle Feibush (1962) reported a single case of tuberculosis of the clavicle

MATERIALS AND METHODS

Twelve cases of tuberculous osteomyelitis of the clavicle attending Willingdon Hospital New Delhi and the H P Medical College Simla from 1966 to 1971 were studied

A detailed history was recorded a clinical examination of the patients was carried out and they were investigated roentgenologically Histopathological examination of the material was made in operated cases Serological tests were carried out to exclude syphilis

OBSERVATIONS AND DISCUSSION

The ratio of males to females involved was 3 2 in the previously recorded cases, whereas it was 1 2 in the present series Average



Figure 3a Clinical photograph of a patient showing tuberculous ulcers over both acromial ends of the clavicle

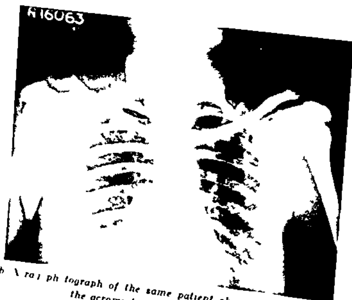


Figure 3b X-ray photograph of the same patient showing destructive lesions at the acromial ends of both clavicles



Figure 2 Roentgenogram showing a cystic lesion with a sequestrum at the sternal end of the left clavicle

cases in our series, the number of lesions elsewhere constituting a much higher incidence of associated skeletal tuberculosis when compared with the previous authors

Roentgenograms showed destructive lesions in four cases, cystic rarefaction in three cases, sequestrum formation in two cases (Figure 2), irregular thickened clavicle in three cases and proliferative lesion in one case Jensen (1959) reported involvement of the articular surface of the clavicle in all cases whereas it was seen only in one case with bilateral tuberculosis of the clavicle in the present series (Figure 3a,b)

Histopathological examination confirmed the diagnosis The material removed by curettage of the lesion in seven cases showed typical tubercle formation and caseation Serological tests for syphilis were negative in all the cases

Of Sirkin & Baumgartner s recorded cases, treatment was surgical in 28 patients and conservative in 2 patients Jensen carried out a combination of surgical and anti-tubercular treatment in five cases, resulting in healing of the wound We carried out curettage of the lesion in seven cases followed by anti-tubercular therapy and in the other five cases only conservative treatment was given Drugs given were usually a combination-of-three injection of streptomycin 1 GM intramuscularly daily up to 90 to 120 gm with Isoniazid hydrazide



Figure 3 a Clinical photograph of a patient showing tuberculous ulcers over both acromial ends of the clavicle



Figure 3 b X ray photograph of the same patient showing destructive lesions at the acromial ends of both clavicles

300 mg and para Amino salicylic acid 10–12 gm daily for approximately 1 to 1½ years

SUMMARY AND CONCLUSION

A detailed study of twelve cases (including two with bilateral lesion) of tuberculous osteomyelitis of the clavicle was carried out The following points emerged from this study

1 Tuberculous osteomyelitis of the clavicle was seen more frequently in females and usually during the second decade
2 The lesion was localized in the metaphysis of either end of the clavicle except in one case where the lesion was diaphyseal
3 Such lesions were commonly associated with osseous tuberculous lesions elsewhere
4 Anti-tubercular treatment sometimes combined with curettage of the cavity and excision of the sinus tract led to healing of the lesion in all the twelve cases

ACKNOWLEDGEMENT

The authors would like to thank Dr N D Aggarwal Professor of Orthopaedic Surgery Government Medical College Patiala and Dr Dessgupta Pathologist Willingdon Hospital New Delhi for their constructive suggestions on the writing of this paper

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LESIONS OF THE VOLAR FIBROCARTILAGO IN FINGER JOINTS

A 2 Year Material

J T MØLLER

Accepted 3 xii 73

Interest in the pathological-anatomical changes in the sprained finger dates essentially from investigations by Moberg & Stener (1953) and Stener (1963) in whose work it was pointed out that exact diagnosis with determination of localization and distribution of the ligamentary injuries is decisive for treatment and prognosis

Just as the collateral ligaments hinder lateral movements, the fibrocartilago volaris functions as the passive retardation of non-physiological extension movements in the finger joints Therefore, lesions of the volar fibrocartilage occur during trauma involving a moment of hyperextension The trauma most often consists of a combination of hyperextension, sideways deviation and axial trauma with simultaneous injury to the collateral ligaments and/or bone ends adjacent to the joints

In the four ulnar metacarpo-phalangeal joints the fibrocartilage is very thin In the interphalangeal joints it consists of two lateral, solid strands and a thin, axial part, ending proximally in a free border (Gad 1967) Ruptures in these joints can occur in one of the proximal insertion corners, being unilateral, or in both, viz total, or in the distal part

The diagnosis lesion of the fibrocartilago volaris is characterized by local tenderness and pain on hyperextension With flexion from this position the pain disappears but reappears near the point of maximum flexion

This publication concerns itself with the results of a follow-up investigation of conservatively treated cases with the aforementioned diagnosis, with or without subluxation, luxation or volar avulsion The

lesions are divided into types, based on the clinical and roentgenological findings, and treatment and prognosis is evaluated in relation to this division.

MATERIAL AND METHODS

A total of 139 injuries were treated between Sept 1970 and Sept 1972, of which 57 were women and 82 were men 54 per cent were in the age group 11-15 years, 24 per cent were 16-20 years old, and 12 per cent were from 21-25 The investigation covered 109 patients with 111 injuries, consisting of 121 fingers and 138 joints A follow-up study was performed 1 to 24 months, with an average of 8 4 months, after the injury. The standard treatment was immobilization of the finger with the joint in semi-flexion with the help of a flexible, foam rubber covered aluminum splint for 2 to 4 weeks Injuries with total rupture of the collateral ligaments are not included in the investigation

Aetiology

Balls striking the fingers accounted for 39 per cent, falls 27 per cent, struck fingers 10 per cent and others 24 per cent

Sequelae are graded in the following manner

+ cold water and forceful loading brings on mild pain
++ moderate pain from tapping or from performing normal work
+++ considerable pain daily, symptomatic restriction of movement, dystrophic appearance

Movement restriction and passive hyperextension possibility without subjective sequelae were less than 10°, and are not listed as sequelae

Statistics

χ^2 test and Yates' correction with 5 per cent as significance limits

At the primary investigation of a joint with hyperextension trauma the lesion corresponding to the area with the maximum soreness of the volar fibrocartilage was found with the help of a narrow blunt instrument This localized tenderness lasts for up to several years after healing or defective healing and can be demonstrated most easily during simultaneous passive hyperextension of the joint

RESULTS

On the basis of journal notes, X-rays and the clinical findings of the follow-up investigation the lesions could be divided up into three groups and nine types (Figure 1) Group 1 consists of joints with normal configuration and movement, but with a unilateral soreness on the side of the proximal insertion The joints in group 2 had bilateral

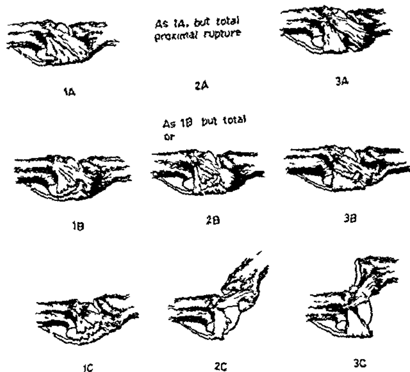


Figure 1 In group 1 the lesion is unilateral and proximal in group 2 it is total and proximal In group 3 the lesion is distal and occurs with or without bone fragmentation The types marked B have simultaneous lesion of the collateral ligaments C stands for luxation or subluxation

proximal soreness In group 3 are listed the joints where the soreness was localized in one or both of the distal insertion corners, with or without volar bone fragments The number of lesions with *bone fragments* make up 42 per cent of group 3 The types marked B in Figure 1 had thickening corresponding to an earlier lesion of the collateral ligaments while the types marked C were primarily luxated or subluxated

Rupture of the middle of the volar fibrocartilage happens only rarely and in such a case there exists the possibility of interposition of the distal piece as illustrated in Figure 1, 2 B, C

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TYPES



1A

As 1A, but total proximal rupture

2A



3A



1B

As 1B but total or



2B



3B



1C



2C



3C

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3*

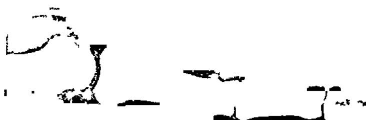


Figure 2 a



Figure 2 b

Unilateral proximal lesion, type 1 A healed with periost reaction, is shown in Figure 2 a b

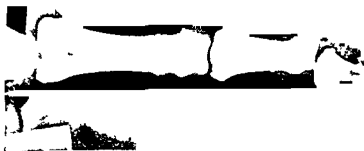


Figure 3 shows subluxation, type 1 C



Figure 4 shows total proximal rupture with instability type 2 C on a 38 year old woman who 6 months later had normal finger movements and no annoyance

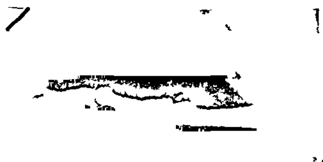


Figure 5 shows an unhealed fragment type 3 A



Figure 6 shows luxation with volar fragment, type 3 C.

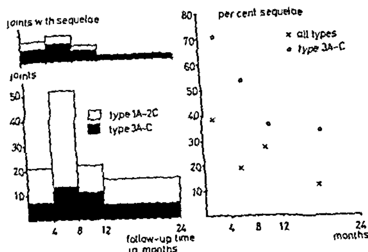
Some of the types can be demonstrated roentgenologically. Type 1 A can be so demonstrated, when simultaneously with the lesion some of the periosteum is displaced, giving rise to bone formation (see Figure 2 a, b).

Movement (average given in parentheses)

Group 1 had normal movement. Type 2 A often had a possibility of passive hyperextension of 15–30° (15°), and sequelae were correlated with more than 15° hyperextension. Types 2 B, C had an average of 5° hyperextension. Types 3 A, B often had 10–15° (7°) flexion defect and 10° (4°) increased extension. Type 3 C had 10–15° (10°) flexion and 10–15° (7°) extension defects.

Prognosis

The number of sequelae according to the particular types of lesions appears in Table 1. The frequency was 11 per cent for the proximal and 50 per cent for the distal lesions, immobilized for 3 to 4 weeks ($P < 0.01$). There were significantly ($0.05 > P > 0.02$) more women than men with sequelae in group 3, namely 66 per cent women against 33 per cent men, and for types 3 A, B without fragments, 83 per cent women against 17 per cent men ($0.1 > P > 0.05$). The effect of immobilization for 3 to 4 weeks as compared with 2 weeks or shorter was significantly better for type 2 A. There was no difference for types 1 A–C. For the other types, the numbers were too small for the effect to be properly evaluated.



ipure 7 *The relationship between follow-up time and sequelae for all injuries and for group 3*

Table 1 The table shows the great difference in frequency of sequelae between proximal and distal lesions Fourteen of the joints in types 3 A, B had volar bone fragments four had sequelae In type 3 C, four had volar fragments and three had sequelae

		1 A	1 B	1 C	2 A	2 B	2 C	3 A	3 B	3 C	Total
Immobilized 3–4 weeks											
Type		1 A	1 B	1 C	2 A	2 B	2 C	3 A	3 B	3 C	Total
Number		33	13	6	14	2	6	17	8	12	111
Seq	+	2	1	1	2	1		6	3	5	21
	++									2	2
	+++			1					1	1	3
Immobilized 2 weeks or less											
Number		13		3	4		1	5		1	27
Seq	+				2			3			5
	++				1		1				2
	+++										

Of 14 patients, nine women and five men with type 3 A, B lesions with volar fragments, all in P I P joints, four had sequelae All these were women and the sequelae were related to unhealed fragments Three out of four patients with type 3 C with fragments had movement

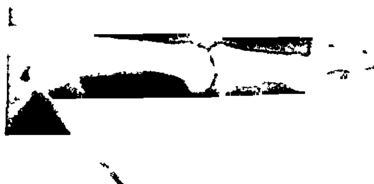


Figure 6 shows luxation with volar fragment type 3 C

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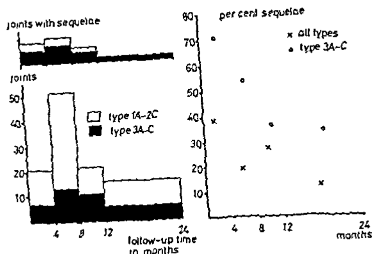


Figure 7 The relationship between follow-up time and sequelae for all injuries and for group 3

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Seq	+	2	1	1	2	1		6	3	5	21
	++									2	2
	+++			1					1	1	3
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Seq	+				2			3			5
	++				1		1				2
	+++										

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43 per cent of the lesions are unilateral and proximal, has great economic significance in terms of sick-days saved

SUMMARY

A total of 109 patients with 138 finger injuries with lesion of the volar fibrocartilage, with or without luxation or avulsed volar bone fragment, were examined an average of 8 4 months after the accident Treatment consisted of immobilization in a flexible, foam-rubber-covered aluminium splint for 2 to 4 weeks

Based on the clinical and roentgenological findings the lesions could be divided into three groups unilateral proximal, bilateral proximal (total), and distal, and nine types, depending upon possible simultaneous damage to the collateral ligaments or luxation An essential symptom in the dividing into groups has been the distinct soreness in the injured part of the fibrocartilage Soreness can be demonstrated at the primary examination, and lasts for up to several years after healing A considerably higher frequency of sequelae was found in the distal lesions and the frequency was twice as high for women as for men In the case of distal lesions without luxation or avulsed volar fragment the difference due to sex was even greater

It is concluded that unilateral proximal lesions require immobilization for only 2 weeks, whereas other types should be immobilized for 3 to 4 weeks Fracture dislocations and lesions where X rays during extension of the joint show dislocation of a volar bone fragment should be treated surgically, for example, by fixation with pull-out wire or, in the D I P joints, possibly with arthrodesis

ACKNOWLEDGEMENT

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restrictions and annoyance Figure 7 shows the relationship between the frequency of sequelae and follow-up time for group 3 and for all the injuries

DISCUSSION

Only treatment results of materials consisting of types with bone fragments with or without luxation are published in the literature Lee (1963) reported 22 cases with avulsed fragments without luxation, treated with plaster cast for 14 days Of these 23 per cent had annoyance after 6 years In the present work it was found that, after an average of 9 months' follow-up time, 28 per cent had sequelae, all correlated to unhealed fragments, while the frequency of sequelae without fragments was 50 per cent (the difference was not significant) Also included in Lee's cases are 7 fracture dislocations, treated for 18 days with plaster cast Five had annoyance after 4 years In this investigation 3 out of 4 with fracture dislocations had annoyance Robertson et al (1946) operated on 7 fracture dislocations and fixed the fragments with a three-wire system They all improved but the observation time was only one week Wilson & Rowland (1966) fixed 15 cases with Kirschner wires and obtained decidedly good results for the inhomogeneous materials Moberg & Stener used pull-out wire in their case reports with good results

Interposition of the distal piece of a ruptured fibrocartilage causes locking and flexion defects For this reason, normal movement must be assured before the joint is immobilized Proske (1926) and Stener (1963) have described lesions of this type discovered during the course of operations The present study included a patient whose insufficient reposition was considered to be the cause of a 45° flexion defect The patient did not desire an operation Locking with extension defects can be caused by a lesion in the capsules between the collateral and the ligamentum accessorium (Kolle-Jørgensen 1962) and osteophytes on the capitulum in arthritic joints (Goodfellow 1961)

Previously, we have treated fibrocartilage lesions by immobilization for up to 5 weeks, later 2 to 4 weeks Now we would recommend 2 weeks for proximal, unilateral lesions and 3 to 4 weeks for the others An operation is recommended in those cases where X-rays during extension of the joint show dislocation of a volar fragment

The reduction in immobilization time which can be realized in this manner in a material such as that under consideration here, where

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SPINAL INTERMITTENT DYSBASIA

Sven S. Olsson & Bent Sodemann

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The symptom of intermittent claudication or dysbasia is common and well known as an indication of occlusive arterial disease, with pain in the lower extremities being produced by muscular ischaemia during exercise and relieved when exercise is interrupted. In this connection the term "dysbasia" is nowadays often preferred to "claudication", as pain during walking and inability to continue walking rather than limping is the characteristic feature of this group of disorders. A number of other conditions can produce symptoms almost identical with those of arterial intermittent dysbasia and are often referred to as "pseudoclaudication". This report will deal with the clinically well defined condition where a spinal stenosis causing compression of the cauda equina is the origin of the disorder. A review of the literature on this subject will be given. The condition is rather uncommon and during the period 1970 through 1973 only six patients have been operated upon with this diagnosis at the Department of Orthopaedic Surgery II, University of Gothenburg. Four of these cases will be described in detail as they illustrate the diagnostic and therapeutic difficulties of this condition.

CASE REPORTS

Four patients with typical histories of spinal intermittent dysbasia and with clinical and radiological characteristics of this syndrome will be reviewed. The preoperative investigations in all cases include studies of the arterial blood flow by means of plethysmography and *oscillometry*, in no case revealing any abnormality.

Case 1. F. H.

A 5[illegible]-year old factory worker, first seen at our clinic in September 1970, who had for one year had an increasingly *disabling* low back pain radiating into both legs brought on by walking 100–200 metres. Pain was predominant in the right leg and

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Figure 2 Case 1 Myelography after removal of the right half of the L III lamina shows filling of the subarachnoidal space with deep impressions both anteriorly and posteriorly on a level with the lowest discs



abnormally thick laminae, a reduced interpeduncular distance was noted The laminae of L III, L IV and L V were removed together with sufficient parts of the facets of the intervertebral joints to unroof the lateral recesses and expose the nerve roots After operation the symptoms gradually subsided and the patient returned to his rather heavy work after 6 months

Case 2—G B

A 46-year old truck driver was operated upon in 1963 with extirpation of a sequestrum from the L IV–L V disc after a 6 months' history of right sided sciatica with clinical and myelographical signs of a disc herniation The patient was free from pain for 3 months after the operation but then low back pain re appeared radiating into both legs, most pronounced in the left leg A myelography, done 8 months after the operation, showed defective filling of the subarachnoidal space at the L IV L V disc level, interpreted as an effect of postoperative adhesions The patient was recommended rest and treated with analgesics without relief He had



Figure 1 Case 1 Myelography with water soluble contrast medium Almost total block at the level of the L II–L III disc

accompanied by paraesthesias and weakness the *muscles of the legs* felt like jelly The *pain* and weakness disappeared after sitting down for a few minutes but paraesthesias could persist also during rest On examination a diminished Achilles tendon reflex and slightly weaker triceps surae muscle on the right side were the only positive findings Peripheral pulses were normal Myelography with contrast injection between L I and L II showed an almost total block at the level of the L II L III disc (*Figure 1*) At operation in October 1970 a slight protrusion of this disc was noted but the dural sac pulsated normally and the nerve root was freely movable At the next lower level the pulsations were extinguished but occurred normally after the right half of the L III lamina had been removed A postoperative myelography was made to exclude the presence of an intradural expansive process below the explored levels The filling of the subarachnoidal space was now complete but with deep impressions both *anteriorly* and posteriorly on a level with the *three lowest lumbar discs* (Figure 2) No further intervention was made at this stage as the patient became symptom free after the operation except for a slight persisting discomfort in his left leg and also could go back to work He was well for 2 years but from December 1970 symptoms of the same character and severity as before successively returned Decompressive laminectomy was performed in April 1973 Especially at the L IV L V level a marked reduction of the space of the spinal canal was present with failure of the dural sac to pulsate below the level In addition to a reduced distance between the bulging discs and the

igure 3 Myelography showing total block at the level of the LIV–LV disc and impressions in the subarachnoidal pace at the levels of the two next cranial discs



Achilles tendon reflex was absent but no motor or sensory disturbances were noted The straight leg raising test provoked pain in the back at 45 degrees bilaterally Peripheral pulses were normal. A walk way test was interrupted after 290 metres because of increasing cramp like pain in both legs Ergometry showed excellent physical capacity and no symptoms developed Myelography revealed a total block at the level of the LIV LV disc and deep impressions in the sub arachnoidal space at the levels of the two next cranial discs (Figure 3) In April 1973 decompressive laminectomy of LIV and LV was performed and the dural sac and its contents were found to be compressed in the abnormally narrow spinal canal No cerebrospinal fluid leaked through an accidental opening in the dura The sagittal diameter of the spinal canal was much reduced by abnormally thick and horizontally placed laminae and by hypertrophic ligamenta flava In addition a disc sequestrum was found, herniating from the ruptured LV SI disc, and compressing the left SI root The patient was relieved from his symptoms after operation except for a slight and occasional aching in his left ankle region and he returned to full work 5 months after operation

not been able to work during the period from 1963 to December 1970 when he was again admitted to our clinic He was then unable to walk more than 100 metres because of weakness and numbness in his left leg and pain in the lumbosacral region radiating into both legs All symptoms subsided at rest Tendon reflexes were normal and no motor weakness was found Sensation was slightly impaired in the lateral aspect of his left foot and the straight leg raising test was positive at about 60 degrees bilaterally Myelography showed a marked anterior impression with incomplete filling of the subarachnoidal space at the L IV–L V disc level A herniated disc was suspected and a partial left sided hemilaminectomy was carried out in March 1971 A bulging disc and osteophytes on the margins of the vertebral bodies were the only pathological findings In spite of the limited decompression the patient was completely relieved of his symptoms and able to return to work and he has remained symptomless since then

Case 3—A A

A 67 year old pensioner who had for 7 years complained of pain in the sacral region and in both legs most prominent in the calves with numbness and tingling sensations in the feet and ankle regions The symptoms were evoked by walking for 3 4 minutes and disappeared completely after a few minutes rest Peripheral pulses were normal and there were no signs of circulatory disturbance No neurological abnormalities were found Radiographs of the lumbar spine showed advanced spondylarthritis with large osteophytes surrounding the greatly reduced three lowest discs and also affecting the intervertebral joints Myelography showed deep impressions in the subarachnoidal space on a level with the three lowest discs with medial dislocation of the corresponding nerve roots In November 1972 decompressive laminectomy of L III L IV and L V was performed Beginning distally we noted a much reduced sagittal diameter of the spinal canal from which the dural sac protruded into the laminectomy opening The normal pulsations of the dura synchronous with respiration were absent at this stage but appeared after completion of the laminectomies The decompressive procedure was not extended laterally to unroof the lateral recesses Two weeks after operation the patient could walk for 20 minutes without the distress that would before have forced him to rest after 4 minutes One year after operation he is completely symptom free in his right leg but experiences a slight aching and tiredness in his left leg after about 30 minutes walk causing him to rest for a short while

Case 4—B W

A 43 year old labourer who had for 3 years suffered from low back pain radiating into both legs and diffuse numbness in both legs after walking for 10–15 minutes He was able to work only for short periods Complete relief occurred during rest and the patient noted that he could ride a bicycle without distress At this stage decompressive laminectomy was planned In December 1972 acute aggravation occurred with pain from the left buttock along the dorsal aspect of the left leg to the heel This pain was continuous not disappearing during rest regardless of position When the patient was seen at our clinic in February 1973 his left

Figure 3 Myelography showing total block at the level of the LIV LV disc and impressions in the subarachnoidal space at the levels of the two next cranial discs



Achilles tendon reflex was absent but no motor or sensory disturbances were noted The straight leg raising test provoked pain in the back at 45 degrees bilaterally Peripheral pulses were normal A walk way test was interrupted after 290 metres because of increasing cramp like pain in both legs Ergometry showed excellent physical capacity and no symptoms developed Myelography revealed a total block at the level of the LIV LV disc and deep impressions in the sub arachnoidal space at the levels of the two next cranial discs (Figure 3) In April 1973 decompressive laminectomy of LIV and LV was performed and the dural sac and its contents were found to be compressed in the abnormally narrow spinal canal No cerebrospinal fluid leaked through an accidental opening in the dura The sagittal diameter of the spinal canal was much reduced by abnormally thick and horizontally placed laminae and by hypertrophic ligamenta flava In addition a disc sequestrum was found herniating from the ruptured LV–SI disc, and compressing the left SI root The patient was relieved from his symptoms after operation except for a slight and occasional aching in his left ankle region and he returned to full work 5 months after operation

DISCUSSION

Verbiest in 1954 was the first to associate the clinical picture of radiating pain, sensory disturbance and impairment of motor function in the lower limbs, *precipitated by walking or standing and relieved* by rest, with a developmental narrowing of the lumbar canal Since then several authors have described this clinical entity and thrown light upon its pathogenesis (Epstein et al 1962, Teng & Papatheodorou 1963, Joffe et al 1966, Spanos & Andrew 1966, Jones & Thomson 1968, Schatzker & Pennal 1968, Kavanaugh et al. 1968, Ehni et al 1969, Weiser 1971, Weber & deKlerk 1973, Nelson 1973)

The significance of a congenital narrow lumbar spinal canal with shortened interpeduncular distance, short, broad peduncles and abnormally thick and horisontally placed laminae as the basic disorder is pointed out in many reports (Jones & Thomson 1968, Schatzker & Pennal 1968, Ehni et al 1969, Weber & deKlerk 1973) This narrowing of the spinal canal is in itself symptomless, but when degenerative changes affecting intervertebral discs, vertebral bodies and intervertebral joints further encroach on the space in the spinal canal, the function of the cauda equina is interfered with and symptoms are produced Several explanations have been given regarding the mechanism of this interference Kavanaugh et al (1968) suggested that increased pressure of the cerebrospinal fluid below the level of the block causes collapse of veins with resultant anoxia of the nerve trunks Blau & Rushworth (1958) showed that exercising a hindlimb in the mouse produced local increased vascularity in the corresponding segment of the spinal cord and dilatation of the veins of the spinal nerve roots Blau & Logue (1961) suggested that the symptoms of spinal intermittent dysbasia were produced by increase in pressure on abnormally confined nerve roots due to vasodilatation during exercise If the space occupied by the nerve root is so diminished that dilatation of the vessels corresponding to the functional demands is made impossible, anoxia of the nerve tissue will also impair its function Many authors stress the mechanical factors, noting the correlation between posture and symptoms Breig (1960) in cadaver studies showed that extension of the lumbar spine caused a shortening of the spinal canal, slackening of the ligamenta flava with increase in their cross-sectional area, narrowing of the intervertebral foramina and slight posterior protrusion of the discs, all factors contributing to a narrowing of the spinal canal

Clinical characteristics

Symptoms The clinical history of pain, paraesthesia and weakness in the legs brought on by exercise and relieved by rest is strongly suggestive of arterial occlusive disease affecting the arterial supply to the lower limbs Close questioning, however, will reveal details that differentiate arterial from spinal intermittent dysbasia The patient with occlusive disease describes an aching, cramp like pain in the calves and thighs brought on by walking a fairly constant distance and also by other activities such as cycling The pain is promptly relieved when the patient stands still for a few minutes Walking up stairs or an incline will precipitate the pain sooner, whereas walking at a slower pace will delay the onset of pain In patients with arterial occlusive disease paraesthesias and weakness are usually not prominent symptoms

In spinal intermittent dysbasia the pain is often vaguely described as located in the low back extending to the buttocks and legs, as a rule without a radicular pattern The distress is often dominated not by pain but by paraesthesias and weakness, described as numbness tingling heaviness and unsteadiness The symptoms can be precipitated not only by walking but also by certain positions such as standing and even lying with the back straightened and often are not relieved unless the patient sits down or bends forward In some cases symptoms develop when the patients walk down stairs but not when they climb stairs and a patient who can walk only for a few minutes may be able to ride a bicycle long distances without distress

Signs The presence of normal peripheral pulses both at rest and after exercise in a patient with a history of intermittent dysbasia should make the examiner suspect a spinal origin of the disorder There is no specific clinical abnormality associated with spinal intermittent dysbasia and this discrepancy between symptoms and signs is often striking Movements of the lumbar column are often almost or totally unrestricted and painless and the straight leg raising test may be normal Sensory disturbances are sometimes found, usually in the L5 and S1 dermatomes but are often absent Muscular atrophy and weakness may occur but are seldom pronounced Reflex asymmetry is a common finding the Achilles tendon reflex being the most frequently affected A repeat examination after the patient has provoked symptoms by walking an appropriate distance will often reveal neurological signs of great diagnostic importance One or more tendon reflexes may

DISCUSSION

Verbiest in 1954 was the first to associate the clinical picture of radiating pain, sensory disturbance and impairment of motor function in the lower limbs, precipitated by walking or standing and relieved by rest, with a developmental narrowing of the lumbar canal Since then several authors have described this clinical entity and thrown light upon its pathogenesis (Epstein et al 1962, Teng & Papatheodorou 1963, Joffe et al 1966, Spanos & Andrew 1966, Jones & Thomson 1968, Schatzker & Pennal 1968, Kavanaugh et al 1968, Ehni et al 1969, Weiser 1971, Weber & deKlerk 1973, Nelson 1973)

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intermittent dysbasia and at operation both diagnoses were verified Several similar cases are reported in the literature and it may be valuable to keep the possibility of such coincidence in mind when planning disc surgery

SUMMARY

Spinal abnormalities causing a reduction of the space within the spinal canal and a compression of its contents have for the last two decades been reported by several authors as a clinical entity with symptoms strongly suggestive of the "intermittent claudication" or "intermittent dysbasia" well known as a symptom of arterial occlusive disease compromising the blood supply to the lower limbs The term "spinal intermittent dysbasia" is proposed for this clinical entity

Some clinical characteristics that provide valuable clues in distinguishing a spinal from a vascular disorder are presented and four cases known to the authors are reviewed

Myelography should be performed to verify the diagnosis and give information necessary in planning the operation The general opinion that treatment consists of laminectomies of adequate extent both longitudinally and laterally to decompress the dural sac as well as the nerve roots is consentient with our experience

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have disappeared and motor and sensory disturbances, as a rule without a distinct radicular pattern, may be demonstrated

Radiological findings Radiographs of the lumbar spine usually show spondylosis with narrowing of disc spaces and osteophyte formation If advanced, these changes alone might be responsible for the narrowing of the spinal canal and compression of the cauda equina that produces the symptoms Developmental abnormalities of the neutral arches resulting in reduced sagittal and transverse diameters of the spinal canal, however, have been shown by many authors to be of fundamental importance (Jones & Thomson 1968, Weber & deKlerk 1973, Nelson 1973) Shallowness of the lateral recesses containing the nerve roots is an important part of the anomaly and must be considered at operation (Schatzker & Pennal 1968, Nelson 1973) Several attempts have been made to produce guides for measuring the size of the spinal canal on plain radiographs (Jones & Thomson 1968, Weber & deKlerk 1973) To obtain a definite diagnosis, myelography should be performed The most common finding is an hourglass-like deformation of the subarachnoidal space at one or more levels, with the encroachments as a rule most marked from the dorsal and ventral aspects Often a complete block is present or the nerve roots may be so tightly packed in the compressed dural sac that a myelographic picture suggesting epidural injection is produced

Treatment

Although spontaneous regression of symptoms has been reported (Kavanaugh et al 1968), surgical treatment as a rule is necessary The decompressive laminectomy must be sufficient both longitudinally and laterally to relieve completely the stenosis at all engaged levels A partial, or even total, facetectomy may be necessary to decompress adequately the nerve roots in the lateral recesses

The return of symptoms in our case 1 was regarded as a consequence of inadequately extended decompression both longitudinally and laterally, at the first operation The persistance of some symptoms in case 3 may also be interpreted as a result of inadequate lateral decompression In case 2, however, permanent relief was obtained after partial hemilaminectomies As shown by myelography, the stenosis in this case was limited to one level In case 4 a history of acute debuting sciatica with the clinical characteristic of lumbar disc herniation was superimposed upon the long-standing symptoms suggestive of spinal

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FACTORS IN THE MECHANICAL FAILURE OF THE FEMORAL COMPONENT IN TOTAL HIP PROSTHESIS

Report of Six Fatigue Fractures of the Femoral Stem and Results of Experimental Loading Tests

MARC MARTENS, ETIENNE AERNOUDT, PAUL DE MEESTER, PAUL DUCHEYNE, J C MULIER, RIK DE LANGH & PAUL KESTELIJN

Accepted 9 1 74

Total hip prostheses as a method of surgical treatment of osteoarthrosis are being implanted at a significantly increasing rate

Although the short term results are promising, the late results and late complications are as yet not well documented As far as mechanical problems are concerned, attention has been focused on wear at the articulating surfaces and skeletal fixation of the prosthesis

This paper is concerned with another type of mechanical problem fatigue fractures of the femoral stem A report on the operative, radiological and metallurgical findings in our cases of stem fracture is presented Experimental loading tests have been conducted in an attempt to clarify some aspects of this mechanical failure

CLINICAL MATERIAL

From a total of 56 replacement arthroplasties of the Charnley Muller type, Co, Cr, Mo casting alloy Protasul (C 0 2 0 3 per cent – S 1 per cent – Mn 1 per cent – Fe 2 per cent Mo 5–6 per cent – Cr 25 5–29 per cent – Co Rest) there were fatigue fractures of the femoral stem in six cases We have not, as yet, experienced this complication in any patients from an earlier series of Mckee Farrar or a later series of Charnley stainless steel prostheses

All six patients had apparently had successful replacements and then experienced a sudden onset of pain and a feeling of instability in the affected leg on weight-

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All six patients had apparently had successful replacements and then experienced a sudden onset of pain and a feeling of instability in the affected leg on weight

Table 1

	Age at surgery	Result	Fracture of the stem	Clinical symptoms after failure	Revision
Case 1	68	Painfree No external support	(Dec 1968–July 1970) 20 months postoperatively	Sudden onset of pain and instability Could only walk with a cane	Cracks in the acrylic mantle but no discontinuity
Case 2	65	Painfree Walking with a cane	(June 1969 Sept 1971) 27 months postoperatively	Pain and instability Sudden onset of the complaints after a painfree interval	Not necessary
Case 3	67	Painfree Walking with a cane	(May 1970 Dec 1971) 19 months postoperatively	Pain at the hip and the knee Instability Sudden onset of complaints	The stem is not completely surrounded by an acrylic mantle (cfr picture 3)
Case 4	63	Painfree No external support	(Jan 1970 Aug 1971) 18 months postoperatively	Pain and instability Sudden onset of complaints	Cracks in the acrylic mantle but no discontinuity
Case 5	71	Painfree No external support	(May 1970 Aug 1972) 27 months postoperatively	Instability Sudden onset	No revision necessary
Case 6	74	Painfree No external support	(May 1971–Jan 1973) 20 months postoperatively	Pain on weight bearing Instability Sudden onset of complaints	Revision and replacement by a new prosthesis



Figure 1 X ray check 20 months postoperatively Failure of the stem at the limit of the upper and middle third



Figure 2 Case 2 X ray check 27 months postoperatively reveals the fracture at the limit of the distal and middle third



Figure 3 X ray film 19 months postoperatively reveals the fracture in the middle third of the stem and angulation of the fragments

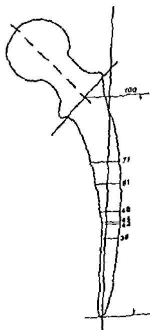


Figure 4 The level of the different stem fractures is indicated A concentration of the levels of failure in the middle third of the stem is noticed



Figure 5 A The acrylic mantle removed at the time of revision through a large window in the lateral cortex did not circumscribe the entire stem

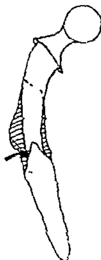




Figure 5 B Reconstruction of the relationship of the stem and the acrylic mantle shows the incomplete covering Particularly the fact that the upper medial edge of the stem is not in contact with cement can cause an unfavourable loading configuration The arrow indicates the level of the fracture at the femoral stem

bearing The details of the failures are summarized in Table 1 All prostheses failed between eighteen and twenty seven months post operatively

Radiographs taken after the onset of pain revealed fractures of the stem of the femoral component with some displacement of the fracture ends, indicating that the metal was not immobilized by the surrounding acrylic (Figures 1, 2 and 3) The sites of failure in terms of percentage of stem length measured from distal to proximal, are shown in Figure 4 The failure site ranged in level from 36 per cent to 71 per cent of the stem length with three of the *six failing at* 40 ± 3 per cent of the stem length The radiographs revealed no abnormal relationship between the femoral stem and acetabular cup nor any malposition of the femoral component

A common finding in all failed cases, however, was that the femoral stem was tilted outwards with regard to the axis of the medullary canal and the tip was near the lateral femoral cortex

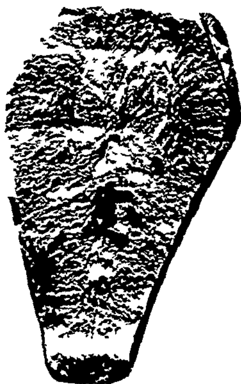


Figure 6 SEM picture by a Cambridge Stereoscan showing the different pattern of failure of the outer third representing the initiating fatigue zone The remaining two thirds of the cross section shows a brittle fracture pattern



Figure 7 SEM picture of the fracture site of the stem (case 3) The outer two thirds of the cross section failed in fatigue and the remaining part followed with a brittle fracture at the time the cross section was weakened enough to allow a sudden brittle fracture of the inner third of the area

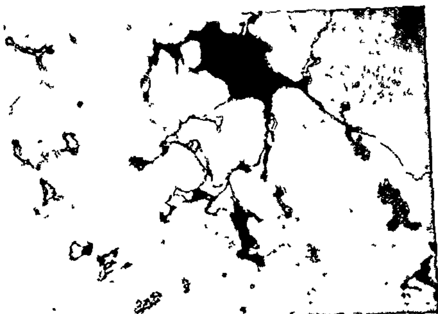


Figure 8 Metallurgical examination shows microvoids of different sizes in the material near the fracture site Magnification 460 ×

A review of the radiographs from non fractured cases revealed a variation in the inclination of the femoral stem in the medullary canal

Operative findings Four of the six cases came to revision because of pain and instability two had insufficient complaints to warrant exploration In three of the four cases explored the femoral prostheses were removed by resection of a large piece of the lateral cortex and an assessment of the acrylic could be made The other case had the femoral component removed from above

Two cases demonstrated cracking of the acrylic Incomplete covering of the femoral stem by the acrylic mantle was seen in the third case and failure occurred at the edge of the defect in the acrylic mantle (Figure 5 A and B)

Metallurgical studies Three of the failed femoral components were studied with a Cambridge scanning electron microscope and with a Reichert MeF2 microscope The latter study was done after the specimens were prepared by grinding and polishing on diamond cloth followed by chemical or electrolytical etching

Examples of the scanning EM findings are shown in Figures 6 and 7 These demonstrate a fatigue failure of the lateral side of the cross section followed by a brittle fracture of the remainder

The metallographic examination revealed a coarse grained cast structure with typical basaltic crystals of a mean diameter of 1 mm which met in the middle These crystals formed a mosaic pattern with scattered rather than longitudinal orientation Several microvoids were seen (Figure 8) As shown in Figure 9 A and B precipitations of eutecticum and impurities at the grain boundaries were also

seen These probably represent a brittle σ phase which is especially prone to occur in cast cobalt alloys The precipitation of this σ-phase can be caused by the presence of impurities or by inappropriate previous thermal or mechanical treatment

A heat treatment was carried out on a specimen at 1300° C for one hour This treatment caused the complete dissolution of the eutecticum and partial disappearance of the precipitations at the grain boundaries (Figure 10) After this thermal treatment only electrolytic etching could make the grain boundaries visible A compression test showed that thermal treatment (1300° C—1 hour) increased the yield stress ($\sigma_{0,2}$) of the material in spite of grain growth which normally decreases the yield stress

In summary it can be stated that grain size grain structure and phases appearing in these specimens are unfavourable for a material that is exposed to impact load while the microvoids observed represent an incidental danger

EXPERIMENTAL STUDY

Because mechanical factors as well as material properties may be involved in the failure of these prostheses an experimental model was designed to test some of these factors

The aim of the experimental study was to obtain an approximation of the stresses at the outer surface of the femoral stem *in vivo* where cracks in the acrylic or incomplete covering of the stem by the acrylic cause an unfavourable loading configuration yielding high tensile stresses at the site of the discontinuity in the acrylic mantle

In order to obtain more meaningful data two types of prostheses were tested under the same experimental conditions The two types were the Charnley Prosthesis Stainless steel 316 L VM—ASTM F 138) Zimmer Company and the Charnley Muller prosthesis Co Cr Mo cast alloy Protasul (C 0 2–0 3 per cent – S 1 per cent Mn 1 per cent Fe 2 per cent Mo 5 6 per cent – Cr 25 5 29 per cent Co Rest) This allows comparison and relative figures where the results as such cannot be aplied to the clinical situation

METHODS

The femoral component of a Charnley Muller Protasul and a stainless steel Charnley prosthesis were imbedded at their stem in an epoxy (Technovit) (Figure 11) The level of imbedding was 57 per cent of their stem length and the stem was mounted vertically so that the applied load on the femoral head at 0° was parallel to the axis of the femoral stem (Figure 12)

The specimen was loaded by an Instron testing machine at the femoral head

Figure 9 A and B Metallography shows the coarse size Eutecticum and precipitations are observed at the grain boundaries

Figure 9 A Magnification 60 ×

Figure 9 B Magnification 450 ×

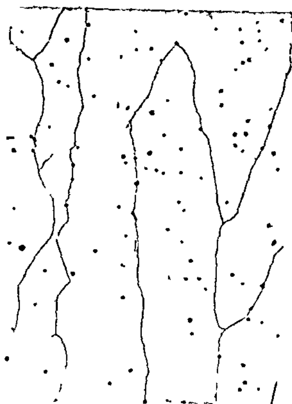


Figure 10 Metallography after thermal treatment (1300°C 1 hour) shows that the eutecticum is completely dissolved and the precipitations at the grain boundaries have almost completely disappeared



Figure 11 Shows the mounting of the femoral component in the epoxy (Technovit) The level is 57 per cent of the height of the femoral stem and two strain gauges are sealed on the outer base at an identical relative height for both prostheses

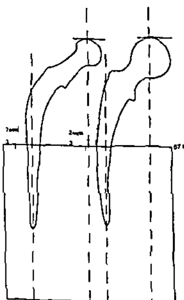


Figure 12 Shows the level of imbedding at 57 per cent of the stem height and the location of the strain gauges It also demonstrates the ± 20 per cent difference in bending moment arm at the stem being the perpendicular distance between the application line of the experimental loading force and the axis of the stem
This does not necessarily represent the moment arm of the resultant joint reaction force in vivo where the direction of the resultant force at the femoral head will be influenced by the possible action of the abductor muscles

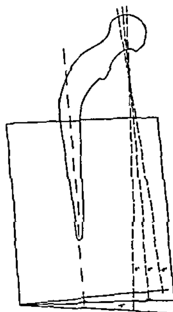


Figure 13 Shows the different experimental loading directions in order to evaluate the influence of the inclination of the stem axis with regard to the axis of the femoral shaft

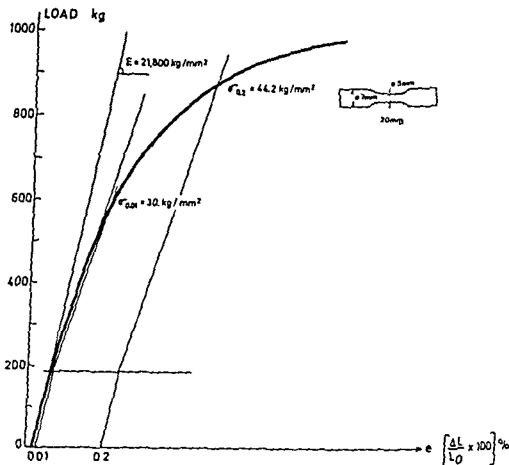


Figure 14.4 A material specimen taken from a Charnley Muller Prosthesis was tested in tension in order to determine

the modules of elasticity ($E \approx 21\,800$ kg/mm²)
– the 0.01 yielding point ($\sigma_{0.01} \simeq 30$ kg/mm²)
the 0.2 yielding point ($\sigma_{0.2} = 44.2$ kg/mm²)
The ultimate tensile strength is 72.6 kg mm²

with interposition of Teflon sheets in order to avoid friction The cross head speed was 0.02 cm/min

Two strain gauges were sealed on the lateral surface at an identical relative position on the stem (Figure 12) The loading at the femoral head was applied in three different directions parallel to the axis of the stem (0°) and with a valgus (–5°) and varus (5°) position of the stem towards the loading application line (Figure 13) This variation in loading direction towards the femoral stem was applied in order to evaluate the effect of inclination of the femoral stem with regard to the femoral shaft axis The degree of possible deviation of the stem from the axis of the femur in the frontal plane is dependent upon the width of the medullary canal but measurements demonstrate that a possible tilting over ± 5° is a realistic average figure The modulus of elasticity and the yielding point were

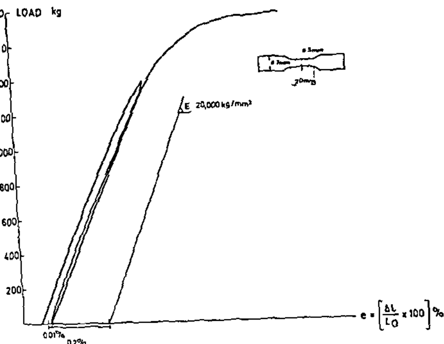


Figure 14 B A stainless steel specimen taken from a Charnley Prosthesis tested in tension reveals

a modulus of elasticity $E = 20\,000$ *kg/mm²*
a $\sigma_{0.01}$ *yield stress* $\sigma_{0.01} = 68$ *kg/mm²*
a $\sigma_{0.2}$ *yield stress* $\sigma_{0.2} = 87$ *kg/mm²*
an ultimate yield stress $\sigma_u = 93$ *kg/mm²*

determined on a tensile material specimen taken from the same type of prosthesis Figure 14)

The 0 01 yield stress was taken as a reference point instead of the 0 2 point which is usually given because the former is more relevant for a fatigue phenomenon, that is explained by a cyclic loading of the material within a critical zone of stress

RESULTS

The relationship of the applied load to the measured strain is shown in Figures 15, 16, 17 and 18 In both types of prosthesis the strain recorded at the lower strain gauge was higher than that at the upper This is explained by the fact that the lower strain gauge is affected by the clamping of the prosthesis in the epoxy and the difference in cross-

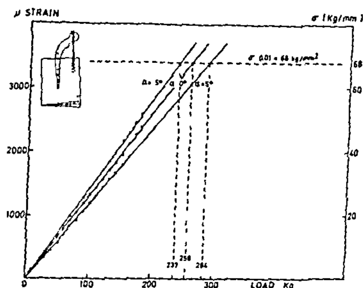


Figure 15 Charnley Prosthesis Readings at the upper strain gauge

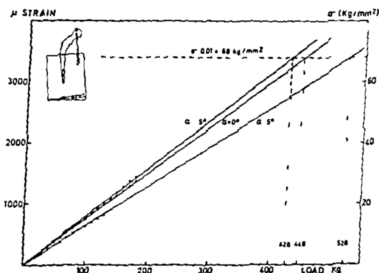


Figure 16 Charnley Prosthesis Readings at the lower strain gauge

Figures 15, 16, 17, 18 Load deformation curves for the two types of prosthesis at a loading direction of $\alpha = 0°$ $\alpha = 5°$ and $\alpha = (-5°)$ The strain gauge readings on the left are converted to stress on the right The loading at the $\sigma_{0\ 01}$ level is indicated and taken as a reference point The actual loading is kept below the yielding point in order to avoid artefacts at reloading by the resultant plastic deformation in the stem or the epoxy Sufficient strain gauge readings were recorded to allow for an accurate extrapolation of the curve

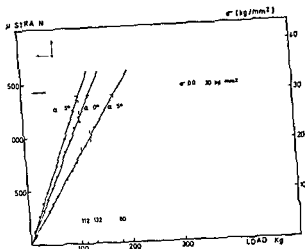


Figure 17 Charnley Muller Prosthesis Readings at the upper strain gauge

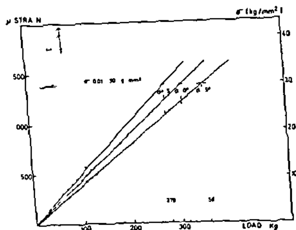


Figure 18 Charnley Muller Prosthesis Readings at the lower strain gauge

sectional area at the different levels The recorded strain at equal loads was higher for the Charnley prosthesis than for Charnley Muller prosthesis

The moment arm of the bending moment at the femoral stem produced by the loading force at the femoral head was about 25 per cent smaller for the Charnley Muller prosthesis in comparison with the Charnley prosthesis (Figure 12) However, this effect was cancelled to some extent because of the smaller cross sectional area of the

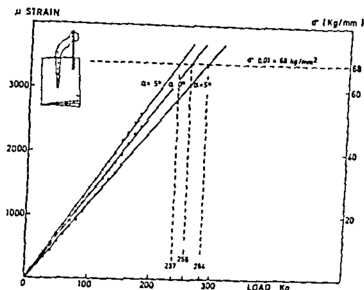


Figure 15 Charnley Prosthesis Readings at the upper strain gauge

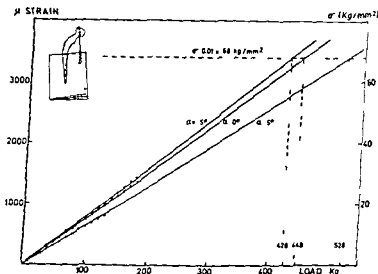


Figure 16 Charnley Prosthesis Readings at the lower strain gauge

Figures 15 16, 17 18 Load deformation curves for the two types of prosthesis at a loading direction of $\alpha = 0°$ $\alpha = 5°$ and $\alpha = (-5°)$ The strain gauge readings on the left are converted to stress on the right The loading at the $\sigma_{0\,01}$ level is indicated and taken as a reference point The actual loading is kept below the yielding point in order to avoid artefacts at reloading by the resultant plastic deformation in the stem or the epoxy Sufficient strain gauge readings were recorded to allow for an accurate extrapolation of the curve

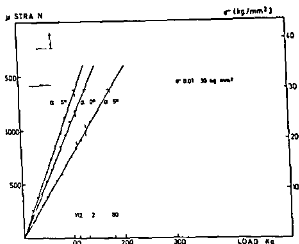


Figure 17 Charnley Muller Prosthesis Readings at the upper strain gauge

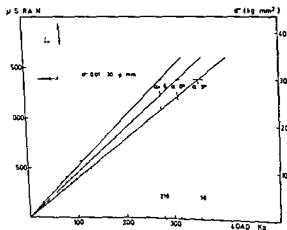


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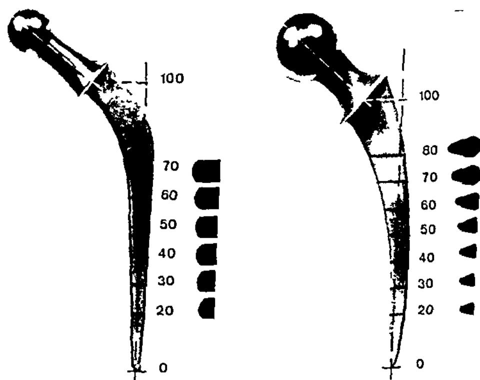


Figure 19 A map of the cross sections of the two types of prosthesis shows the more pronounced tapering of the Charnley Muller type resulting in smaller cross sectional areas at the levels 60 to 20 per cent stem height

Charnley Muller femoral stem at the level of the recorded strain The tapering of the stem is more pronounced in the Charnley Muller prosthesis (Figure 19) resulting in a steeply decreasing cross-sectional area of the stem

Table 2 Load at the femoral head in kg at which the 0 01 yielding point is reached at the level of the strain gauge for different inclinations of the stem of the two types of prosthesis

	Load at the femoral head for 0 01 yield stress at the lower strain gauge			Load at the femoral head for 0 01 yield stress at the upper strain gauge		
Inclination of the stem	+5°	0°	—5°	+5°	0°	—5°
Charnley type	284	256	237	528	448	428
Charnley Muller type	180	132	112	356	313	278
Ratio	1 58	1 94	2 12	1 48	1 43	1 54

Figures 15, 16, 17, 18 demonstrate that the 0 01 yield stress was reached at a significantly lower load for the Charnley Muller prosthesis than for the Charnley prosthesis This difference is mainly due to the different 0 01 yield stress of the material

The 0 01 yield stress is 68 kg/mm² for stainless steel and 30 kg/mm² for the Protasul alloy (Figure 14) The absolute values of the load at the yield stress increase from the valgus (–5°) towards the varus (+5°) position

A 5° deviation of the prosthesis stem from the femoral shaft axis alters the loading conditions at the femoral stem significantly (Figures 15, 16, 17, 18) There was a ± 20 per cent decrease of the loading at the femoral head from a +5° position towards a –5° position to obtain the level of 0 01 yielding stress for the surface covered by the strain gauge

Table 2 shows the load at the femoral head at the 0 01 yielding point for the Charnley and the Charnley Muller prostheses in the different loading directions The ratio of the loads at the 0 01 yield stress for the two prostheses was approximately 1 5

CONCLUSIONS

In our series of total hip replacements using the Charnley Muller prosthesis (Protasul alloy), a fatigue failure at the femoral stem represented a mechanical complication with a high incidence (6/56) It interfered with the clinical result necessitating a revision in some cases From the clinical and experimental studies we can conclude that technical material and mechanical factors are operative in failures of the femoral stem in total hip prostheses

It would seem to be technically important to insert the stem in the varus position with respect to the femoral shaft axis and to insure that it is well covered by acrylic The cracking of the acrylic is a potential danger leading to an unfavourable loading condition of the femoral stem Stainless steel is a more resistant material with regard to fatigue phenomena in comparison with the protasul alloy because of the significantly higher yielding point and its better metallographic structure

SUMMARY

A clinical study of six cases of fracture of the prosthetic femoral stem in Charnley Muller (Protasul) prostheses has been presented

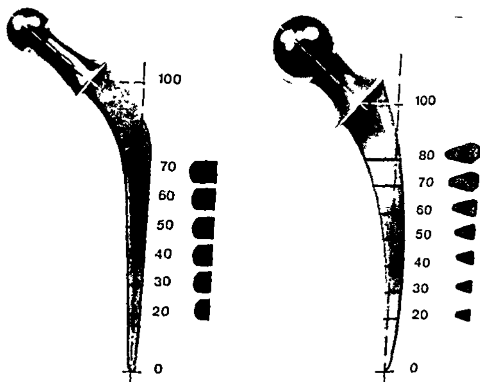


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Martina Hansens Hospital, Sandvika, Norway

SPONDYLOLISTHESIS

A Review of 71 Patients

Asle Verostad

Accepted 3 i 74

With regard to spondylolisthesis many questions still seem to be unresolved The purpose of this follow-up was to find out the results of the treatment as given in this hospital, and to find out if spondylolisthesis is of any importance in pregnancy and for delivery, and if possible, to make a contribution to the discussion on progressive slipping

MATERIAL AND METHODS

A total of 109 patients have been treated for spondylolisthesis at Martina Hansens Hospital during the period 1937–1970 Six patients have been excluded because they were treated primarily at other hospitals Sixteen patients have recently been examined clinically and roentgenologically, the others received a questionnaire Fifty five patients replied to the questionnaire and 32 did not, some were dead Out of the 71 patients who constitute the material in this survey, 29 were treated surgically and 42 conservatively The patients were asked to evaluate the results as excellent good or poor They were asked to distinguish between the result during the first 2 years and the final result. This was because it is felt that many patients do not continue their exercises and therefore the pain may return All 71 patients are considered as having olisthesis, but slipping less than 5 mm may be questionable The degree of vertebral displacement is measured in mm and adapted to the one to four scale of Meyerding (1938)

RESULTS

The age and sex distribution are shown in Table 1 (all 109 patients). There were 62 4 per cent men and 37 6 per cent women This corresponds to the findings of Neugebauer (1956), Friberg (1939) and Meyerding (1941), but Laurent (1958) reported only 46 per cent men in his series of 809 patients

Clinical, radiological and metallurgical factors, which may be responsible for these failures, have been discussed An experimental loading test has been conducted comparing Charnley-Muller and Charnley prostheses at various angles of loading

The conclusion has been reached that the Charnley stainless steel prosthesis has better fatigue resisting properties than the Charnley Muller Co, Cr, Mo casting alloy Protasul, and that the varus position of the femoral stem in relation to the axis of the femoral shaft is of importance in reducing the stresses on the lateral side of the stem

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Table 5 Results of conservative treatment of 42 patients

	First 2 years	Final
Excellent	8	4
Good	20	20
Poor	14	18
Total	42	42

Table 6 Age and sex distribution among 29 patients treated by operation

Age	Men	Women	Total
10–19	2	2	4
20–29	4	–	4
30–39	7	1	8
40–49	3	3	6
50–59	3	1	4
60–69	3	–	3
Total	22	7	29

Conservative Treatment

Forty two patients were treated with physiotherapy with active exercises bedrest and in a few cases a supporting corset The observation period varied from 3 to 24 years (average 10 9 years) Table 2 shows the age at onset of symptoms in this group The location of the lesion was the fifth lumbar vertebra in 27 patients, the fourth in 14 patients and the third in one patient The degree of vertebral displacement is seen in Table 3

Table 4 shows the age and sex distribution in the conservative group Nine of these 42 patients related their symptoms to an adequate trauma The time which elapsed from onset of symptoms to treatment varied from ½ to 37 years (average 12 8 years) All 42 patients had back pain 26 of them had in addition, radiating pain, in some cases typical sciatica Eight patients had a positive Lasegue s sign, 4 patients had sensory disturbances and 7 patients had loss or diminution of ankle jerk

Table 5 indicates the results of conservative treatment, good or excellent in 24 out of 42 cases

Table 1. Age and sex distribution of 109 patients treated for spondylolisthesis

Age	Men	Women	Total
10–19	6	6	12
20–29	9	5	14
30–39	16	7	23
40–49	18	11	29
50–59	9	7	16
60–69	10	5	15
Total	68	41	109

Table 2. Age at onset of symptoms among 42 patients treated conservatively

Age	0–10	11–20	21–30	31–40	41–50	51–60	61–70
No	4	14	8	6	8	–	2

Table 3. Degree of slipping, measured in mm, and adapted to the scale of Meyerding among 42 patients treated conservatively

mm Meyerding	0–10 1	11–20 2	21–30 3	31–total lux 4
M	14	8	1	–
F	14	2	2	1
Total	28	10	3	1

Table 4. Age and sex distribution of 42 patients treated conservatively

Age	Men	Women	Total
10–19	3	2	5
20–29	3	3	6
30–39	2	4	6
40–49	10	4	14
50–59	3	1	4
60–69	3	4	7
Total	24	18	42

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60–69	3	–	3
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Table 4 shows the age and sex distribution in the conservative group Nine of these 42 patients related their symptoms to an adequate trauma The time which elapsed from onset of symptoms to treatment varied from ½ to 57 years (average 12 8 years) All 42 patients had back pain 25 of them had, in addition, radiating pain, in some cases typical sciatica Eight patients had a positive Lasegue s sign, 4 patients had sensory disturbances and 7 patients had loss or diminution of ankle jerk

Table 5 indicates the results of conservative treatment, good or excellent in 24 out of 42 cases

The average stay in hospital was 56.9 days. Eleven patients in the group had changed their occupation and 9 patients had disability insurance.

Table 7. Age at onset of symptoms among 29 patients treated by operation

Age	0–10	11–20	21–30	31–40	41–50
No.	2	12	7	6	2

Table 8. Degree of slipping, measured in mm, and adapted to the scale of Meyerding, among 29 patients treated by operation.

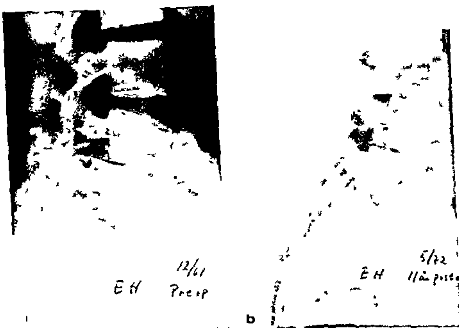
mm Meyerding	0–10 1	11–20 2	21–30 3	31–total lux. 4
M	13	6	3	–
F	5	1	–	1
Total	18	7	3	1

Table 9 Results of operative treatment in 29 patients

	First 2 years	Final
Excellent	8	10
Good	12	8
Poor	9	11
Total	29	29

Table 10 Results of posterior fusion in 11 patients.

	First 2 years	Final
Excellent	5	7
Good	6	3
Poor	–	1
Total	11	11



igure 1 Before (a) and 11 years after (b) lateral intercorporeal fusion Transplant resorbed but patient reports the result as excellent

)perative Treatment

The period of observation in this group of 29 patients varies from 2 .o 26 years (average 12 8 years) The symptoms prior to treatment .asted from 1 to 32 years (average 11 1 years) Age and sex distribution are shown in Table 6 and age at onset of symptoms in Table 7 The location of the lesion was the fifth lumbar vertebra in 22 patients, the fifth and fourth in 2 patients and the fourth in 5 patients Twelve out of these 29 patients operated upon related their symptoms to an adequate trauma Five of them had changed their occupation and 10 of them had disability insurance The degree of vertebral displacement is demonstrated in Table 8, most patients had a slipping of less than 10 mm (Meyerding grade 1)

Fifteen of these 29 patients had radiating pain, 5 had positive Lasegue s sign, 3 had sensory disturbances and 6 had loss or diminution of ankle jerk at the time of operation In the total group of 71 patients, 3 patients had bladder disturbances The average stay in hospital was 106 8 days

The results of operative treatment are listed in Table 9 Table 10 shows the results of posterior fusion, performed in 11 cases In 7 cases a transperitoneal fusion was performed, one with an excellent result and 6 with poor results In 6 cases only a resection of one or more spinous processes was performed, 3 of them with good or excellent results and one with a temporarily good result Simple laminectomy was performed only 3 times, twice with a good result and once with a poor result In one case a lateral intercorporeal fusion was performed The patient reports the result as excellent, although fusion has not been obtained (Figure 1) The last patient had various combined operations He reports the result as good, although he has disability insurance

There were no serious complications of the operative treatment

Spondylolisthesis in Pregnancy and Delivery

In this material 10 women had given birth to 16 children before the onset of symptoms None of them had unusual pain during pregnancy and labour Fifteen women had given birth to 24 children after the onset of symptoms, 7 out of these 15 women suffered from increased pain during pregnancy and 3 during labour There were no cases of prolonged labour or other signs of mechanical obstruction One of the women had 2 spontaneous abortions Two women had avoided pregnancy because of their back lesion

Progressive Slipping

It still seems to be a matter of dispute whether progressive slipping does or does not occur In this series 30 patients had 2 or more X ray examinations, with a time lapse between the first and the last examination varying from 1 to 16 years (average 5½ years) Three female patients presented a total lumbosacral luxation, the progression being observed in one of them (Figure 2) the others were total when first seen They had a pronounced trapezoid shaped fifth lumbar, with a rounding off of the sacrum, but there is no early X ray to determine whether these changes are primary or secondary

Two patients, aged 18 and 51 years, had a progressive slipping of 8 and 10 mm, respectively The last one is demonstrated in Figure 3 Nine patients had a small progression of 2 à mm and 16 patients had no progression at all Those with a small progressive slipping were equally distributed in all age groups



Figure 2 A case of progressive slipping X ray at the ages of 15 years (a) and 29 years (b) Laminectomy at the age of 26

DISCUSSION

Spondylolisthesis obviously causes segmental spinal instability with an increased demand for muscular support This instability causes back pain because of pull on ligaments and nerve roots A great proportion of patients were satisfied with the results of conservative treatment (Table 5) This kind of treatment is usually given a fair chance before operation is considered The young patients with a congenital type of spondylolisthesis might be an exception to this rule In these few cases a fusion operation should be considered The only patient with total luxation treated conservatively in this material was satisfied with the treatment (Figure 4), and the only patient with total luxation treated with laminectomy received no benefit from the operation

The time period between onset of symptoms and treatment varied from ½ to 57 years (average 12 8 years) in the conservative group This fact indicates that the lesion is not very disabling which was also pointed out by Friberg (1939) and Laurent (1958) On the other hand the symptoms probably increase gradually in most cases and at the



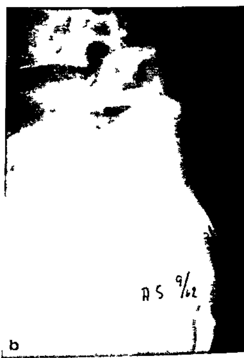




Figure 3 Another case demonstrating progressive slipping X ray at the ages of 35 40 and 51 years (a b c respectively)



Figure 4 The only patient with total luxation treated conservatively X ray at the ages of 34 (a) and 49 (b) She was satisfied with the conservative treatment

time of hospitalization the patients are considerably disabled and in need of corrective treatment

Few women have been treated by operation, probably because they normally have less heavy work than men, and also because they seem to come to treatment a little later, often at the menopausal age (Table 1) The posterior fusion seems to give good results (Table 10) This finding is comparable with similar reports in the literature (Bosworth et al 1955 Friberg 1939, Meyerding 1941) In any case, the posterior fusion seems to have a decreasing popularity nowadays Newman (1973) seems to prefer a posterolateral fusion and Schmorl & Junghans (1971) favour a posterior intercorporal fusion In contradistinction to the transperitoneal route, it allows simultaneous decompression and may also be combined with a posterior fusion Transperitoneal intercorporeal fusion has given poor results in this material, only one out of 7 patients was satisfied Figure 5 demonstrates one of the six patients who was not satisfied, although fusion has been obtained In this material there has been no experience with the posterior intercorporeal fusion, but the method seems reasonable from



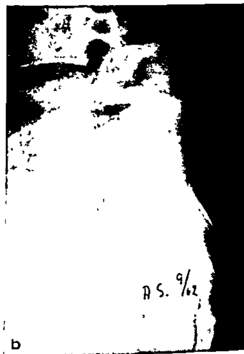




Figure 3. Another case demonstrating progressive slipping X-ray at the ages of 35, 40 and 51 years (a, b, c, respectively)

a mechanical point of view. Gill & White (1965) and Woolsey (1954) consider the fusion operations to be unnecessary. They claim that a decompression operation (laminectomy) gives most patients relief from pain. They have found fibrous masses at the isthmus with various kinds of nerve root compression. Laminectomy has only been performed 3 times in this material, one with poor results (Figure 2) and 2 with good results. This operation is obviously best suited to the cases where sciatic pain and not spinal instability is the main problem. It should be mentioned that Davis & Bailey (1972) reported good results from laminectomy in 83 per cent of cases if there were minimal arthritic changes, and in 58 per cent if there were moderate to severe arthritic changes.

In some cases the disc is considered to be the source of pain, at least if it protrudes. This was probably true in one case. The patient had excellent results from lateral intercorporeal fusion, although fusion was not obtained (Figure 1). With few exceptions the patients in this review had reduced disc height, but myelography has seldom been performed. Alvik (1969) preferred laminectomy and in some cases a transperitoneal intercorporeal fusion at a second stage. Harrington & Tullos (1971) preferred intercorporeal posterior fusion for children.

In this review spondylolisthesis had some importance for the pregnant women as 7 out of 15 women suffered from increased pain during pregnancy and 3 during labour. In 2 of these women the increased pain continued, but in no case did this back lesion seem to cause mechanical obstruction. Dandy & Shannon (1971) reported 14 normal pregnancies and 4 miscarriages whereas 2 labours were prolonged.

There were at least 3 patients with significant progressive slipping in this series of 30 and 9 patients had a slipping of 2–5 mm, which must be regarded as questionable. Some authors (Friberg 1939, Laurent 1958) state that progressive slipping is most likely to occur between the age of 10 and 20. A possible relation between progressive slipping and a trapezoid shape of the fifth lumbar body has been pointed out by Friberg (1939) but Laurent (1958) made some measurements and concluded that there was no such relationship. He thought that the trapezoid shape must be a secondary change. Hitchcock (1940) reported 3 cases of progressive slipping, the patients were 4, 13 and 45 years old. Bosworth et al. (1955) found evidence of progressive slipping in 2 cases. Laurent & Einola (1961) reported this feature in 23 out of 42 cases. It has been noted in this review that a trapezoid shape of the fifth lumbar body coincides with a rounded upper contour of the

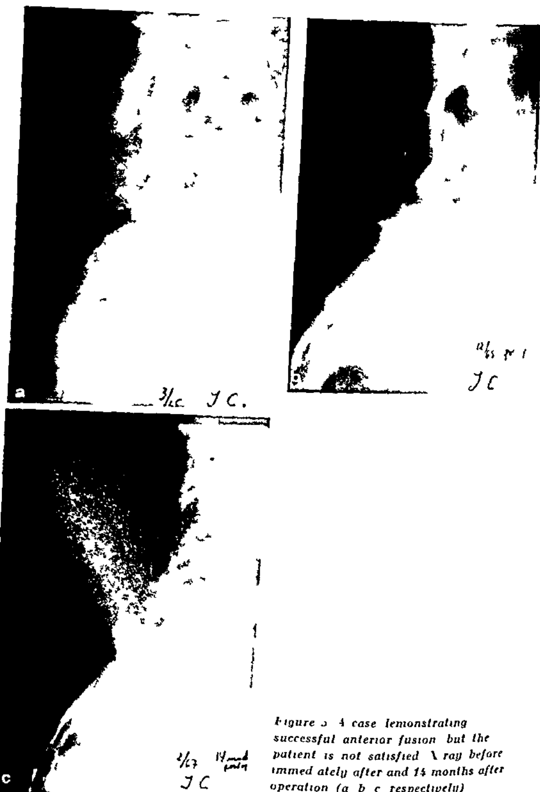


Figure 5 A case demonstrating successful anterior fusion but the patient is not satisfied X ray before immediately after and 14 months after operation (a b c respectively)

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sacrum, and that these features are more pronounced in severe vertebral displacement.

CONCLUSIONS

1. Conservative treatment in the case of spondylolisthesis has a reasonable chance of success
2. Posterior fusion gives a good result in 80–90 per cent, and this is supported by several other authors
3 The pain produced in this lesion often increases in pregnancy and in labour, but probably the women should not be dissuaded from pregnancy
4 Progressive slipping does occur, but in a small proportion of cases

SUMMARY

Seventy-one patients have been reviewed, of whom 42 were treated conservatively and 29 by operation Good results were obtained in 24 out of 42 patients in the conservative group Posterior fusion gave good results in 10 out of 11 cases Transperitoneal intercorporeal fusion only gave good results in one out of 7 cases The importance of spondylolisthesis in pregnancy and delivery is discussed Seven out of 15 patients had increased pain in pregnancy and 3 in labour, but there were no prolonged labours suggesting mechanical obstruction Progressive slipping was demonstrated clearly in 3 cases out of 30 and 9 out of these 30 had a small progressive slipping of 2 5 mm It seems that a trapezoid shape of the fifth lumbar body and a rounded upper contour of the sacrum (ball and socket) predispose to severe vertebral displacement, but this has not been proved These features may be secondary changes

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for 10 minutes Thirty minutes later both hip joints including the upper end of the
[illegible] were carefully removed

circumflex artery and its relationship to the [illegible]
muscle The entire upper end of the femur including the lower part of the fibrous capsule and the round ligament of the head formed the final specimen, which was re fixed in formaldehyde In order to obtain a short decalcification period, some of the specimens were decalcified in a mixture of formic and hydrochloric acid using electrical ionization (Preece 1965) The degree of decalcification was checked frequently by X ray tests and was complete after 100–150 hours Results were acceptable but the method was found to be a little coarse The other specimens were decalcified in Tetrasodium edetate (Gossen & Donohue 1965) This technique gave very fine results but the process was quite slow taking 2–4 months

When decalcification was finished the specimens were bleached in 3½ per cent hydrogen peroxide for two days They were then dehydrated in increasing concentrations of alcohol up to absolute alcohol using an automatic tissue processing machine with a bath change every 24 hours Clearing was performed in two parts of methyl salicylate (Wintergreen oil) and one part of benzyl benzoate Before studying the specimens in a stereoscopic microscope (magnification 6–40) air was driven out using a vacuum chamber

A total of six children were studied Their ages were A 4 months B 1 year, 2 months C 3 years 10 months D 5 years, 2 months E 6 years, 3 months F 9 years 11 months

In child F injection of the left side failed because of damage to the pelvic arteries during autopsy The right femoral head in C was damaged by decalcification and injection was insufficient in A s right and D s left Thus eight specimens were available for study of the arterial supply to the epiphysis of the head of the femur None of the children were known to have had signs or symptoms in the hips before death

Causes of death A Congenital heart disease Down s syndrome B Acute gastro enteritis C Pneumonia after measles leucaemia D, E and F Cerebral contusion or laceration

Nomenclature and brief gross anatomy

The small arteries surrounding the femoral head have been given various names In the present communication the Paris Nomina Anatomica (PNA) will be used, according to Hipp (1962)

The deep branch from the medial circumflex artery, ramus profundus (RP) passes behind the neck of the femur in close relationship to the capsule and the external obturator muscle This artery ends as lateral branches to the epiphysis rami nutricii capitis proximalis (RNCP) Fine retinacular branches from RP pass medially and a little behind the neck towards the head rami nutricii capitis distalis (RNCD) From arteries in front of the neck, retinacular branches pass

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THE ARTERIAL SUPPLY TO THE FEMORAL HEAD IN CHILDREN

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Accepted 3 I 74

The epiphysis of the femoral head begins as an island of bone entirely surrounded by cartilage at about the age of four to six months This island condition continues until the growth cartilage disappears at puberty In the fovea, where the round ligament of the head is placed, connective tissue instead of cartilage is found

The arteries supplying the epiphysis have previously been studied using arteriography (Hipp 1962, Mussbichler 1970) or arterial injections combined with microradiography and clearing of the specimens according to the method of Spalteholz (Trueta 1957, Crock 1967) In these investigations the femoral head has been halved or sliced before study and description It is difficult, however, to perform a three dimensional study on arteriograms even with the use of stereoscopy and it is impossible to visualize the arteries inside the epiphysial bone

This study is an attempt to achieve a better description of the topography of these arteries by investigating the total upper femoral end after injection and clearing by the method of Spalteholz

MATERIALS AND METHODS

Injections were carried out at autopsy in children 8 24 hours after death Thin polyethylene catheters were placed in both external iliac arteries and if possible in the obturator arteries The superficial and deep femoral arteries were then ligated just below the circumflex arteries The vessels were infused for 10 minutes with a 0 9 per cent saline solution using a constant pressure of 90 mmHg Without interruption and using the same constant pressure Microphil®* was then infused

* Microphil® (Canton Bio medical Products Inc P O Box 154 Swartmore Pa 19081 U S) consisted of 32 ml compound and 40 ml diluent To this was added 7 2 ml duroliopaque and just before injection 4 ml curing agent



Figure 2 Same specimen as Figure 1, increased magnification The hip is flexed and the shadow of the deep artery on the obturator tendon shows that the artery is slack (arrow)



F gure 3 Left hea l f A seen fr m beh nd Two arteries appear ascending from the sparse metaphys al network nto the cartilag nous l all The small vessels in the l gament f the hea l (top r ght) are c nfined to the l gament itself

Figure 1. Right hip specimen from L, six years old, seen from behind in the extended position The deep branch of the medial circumflex artery curves snugly around the tendon of the external obturator muscle (arrow).



to the anterior part of the head rami nutrien capitis anteriores (RNCA) Finally the artery in the *round ligament* of the head, arteria ligamenti capitis femoris (ALCF) supplies the head from the opposite side.

The different specimens will be named *Ar* (right specimen from A), Bl (left from B) etc

RESULTS

Macroscopic dissections

This could not be done in A In all the other specimens a normal course of RP just below the external obturator muscle close to the adhesion of the fibrous capsule to the back of the femoral neck was found In every case the artery crossed superficially to the tendon of the muscle as it passed round the tendon before turning to the lateral side of the neck (Figure 1) When the hip joint was extended the external obturator was tense and the artery was found to be stretched over the tendon. In internal rotation of the hip this tension and stretching was even more marked When the hip was flexed the muscle



Figure 5 Same specimen as Figure 4 The network in the fovea and ligament is anastomosing with two of the small branches ascending from the epiphysis into the basal layer of the cartilage (arrow)



Figure 6 Left hip specimen of D seen from in front The greater trochanter is seen to the right The head to the left is poorly illuminated The upper border of the metaphyseal networks runs as a uniform band from the head to the trochanter



Figure 4 Left femoral head of C seen from in front where several thin anterior retinacular arteries (RNCA) traverse the periphery of the epiphysial cartilage Two of the four lateral arteries (RNCP) are seen to the right bending into the epiphysis

and artery were completely relaxed and even more markedly so if the joint was outwardly rotated in addition (Figure 2)

In DI a contusion haemorrhage laterally at the neck at the side of RNCP was found These vessels were thrombosed along their entire course In spite of this the epiphysis was injected in this specimen (Figure 8)

Microscopic findings

Al (aged 4 months) showed two arteries from the metaphysis emerging to the head (Figure 3) Laterally an artery ascended a short distance but did not pass into the cartilaginous head ALCF was seen only in the ligament and did not pass into the head

Br (aged one year) showed a well vascularized epiphysis supplied from a large RNCD a small RNCA and a few small RNCP The ALCF supplied a small area in the fovea but no vessels passed into the epiphysis

Cr and Cl (aged nearly four years) showed richly supplied and well vascularized epiphyses from which small scattered arterial branches passed into the deepest layers of the covering cartilage Four RNCP

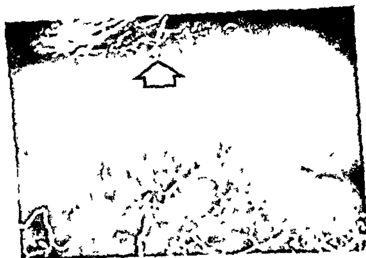


Figure 9 Right hip of E The fovea is seen tangentially (top) One very small anastomosis passes down into the epiphysis (arrow)



Figure 10 The lateral part of the right femoral head of F who was nearly ten years old seen from in front A lateral synovial network ending in several RNCP is seen All of the bone is well vascularised

from the synovial arterial network lateral to the neck entered the epiphysis at an angle of 100 110 A large RNCD and not less than six small RNCA were present (Figure 4) The ALCF supplied a rich network of vessels in the fovea, and from here some very small anastomoses with the epiphysial network were seen (Figure 5)



Figure 7 The metaphysial network of D's right hip seen medially. At the bottom is seen the dense arterial network of the synovial pouch. Here the arteries turn (arrow) before running along the neck into the metaphysis and further up into the epiphysis which is barely seen above the dense surface of the metaphysial network.



Figure 8 The epiphysis of D's left hip seen from in front is well filled through the inferior and anterior retinacular arteries although no injecting material could pass the lateral arteries (right). These were thrombosed outside the cartilage, but some retrograde filling was present.



Figure 12 Same specimen as Figures 10 and 11 showing no communication between arteries of the fovea and the underlying dense epiphysial network

The most likely explanation is that injection of the obturator arteries failed in this patient

Ir (aged six years) showed a increasing number of arteries in the epiphysis which were filled mainly from the RNCP but one RNCD was seen The MCF to the foveal vessels showed in this specimen a small but distinct anastomosis between the arteries in the fovea and those in the epiphysis (Figure 9)

Fr and H (aged nearly 10 years) showed the increasing importance of the RNCP in vascularization of the epiphysis From a true network laterally in the synovium 7 10 arterial branches entered the epiphysis (Figure 10) At the opposite end, just medially, both specimens showed a RNCD also arising from the synovial network and entering the epiphysis *(Figure 11) With the exception of these latter vessels no* anastomoses between the epiphysis and the metaphysis were seen The MCF supplied the fovea *only* and had no communication with the *epiphysis itself (Figure 12)*

Generally speaking the arterial network in the metaphyses was found to be more dense than in the epiphyses The metaphysial vessels were supplied from both the diaphysial (the nutrient artery system) and the synovial network and from arteries entering the bone below the capsule The network in the epiphysis of the greater trochanter was mainly filled by arteries entering the trochanter from the lateral side

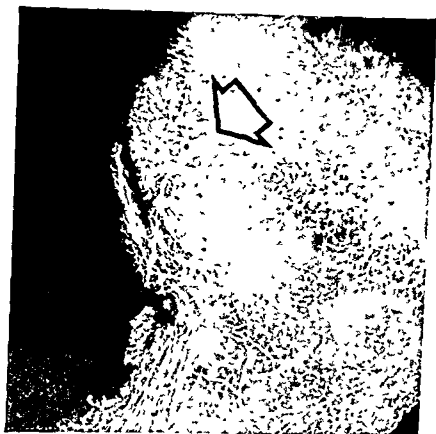


Figure 11 The medial part of the same specimen as in Figure 10 showing a RNCD arising from the synovial network outside the neck and passing the epiphysial cartilage (arrow) into the epiphysis

Dr and *Dl* (aged five years) showed an extensive arterial network in the metaphysis which was particularly dense just below the epiphysial cartilage This "surface" of the metaphysial arteries continued as a uniform band along the lateral border of the neck to the trochanteric part of the metaphysis, and its presence supports the supposition that the growth in the upper end of the femur takes place from a total surface (Figure 6) From a ring of closely packed small arteries at the bottom of the synovial membrane, the retinacular arteries arose and ascended outside the neck, supplied the metaphysis, but ended in two RNCD and one RNCA to the more sparse epiphysial network (Figure 7) In Dr two well-developed RNCP were seen but in Dl, where these arteries were thrombosed due to the contusion, the terminal ends of the RNCP evidenced retrograde filling from the epiphysial arteries to the cartilaginous border The epiphysis was primarily filled through a large RNCD (Figure 8) Neither in Dr or Dl were any ALCF found

arterial supply to the epiphysis after the age of six years, whereas in this study a medial retinacular artery (RNCD) was found passing to the epiphysis at the age of nearly 10 years This study agrees with Wolcott (1943) and [illegible] (1950) in that the vessels in the round ligament of the head [illegible] fovea and have little [illegible]

In the present preparations the anterior retinacular arteries (RNCA) passed more constantly to the epiphysis *than reported by other investigators* It is the author's *opinion* that the lateral, the distal and the anterior retinacular arteries (RNCP, RNCD and RNCA) belong to the synovial network which is more clearly seen with increasing age Possibly this is what Harty (1953, 1966) described as two ring anastomoses The retinacular arteries arise from this synovial network and follow it to the border of the cartilage from whence they continue along the border between metaphysial bone and surface cartilage giving off branches into the metaphysial bone before entering the epiphysis as they pass obliquely through the *edge* of the epiphysial cartilage The lateral arteries (RNCP) become increasingly dominant in the blood supply *to the epiphysis* with increasing age *If the blood supply through these arteries is stopped, the epiphysis will undergo ischaemia especially in children more than 5 6 years of age* This condition persists until the rest of the smaller arteries have grown sufficiently to compensate

SUMMARY

A method used to inject Microphil® into the arteries of the hip region in children of various ages at autopsy is described By macroscopic dissection and microscopic investigation particular attention was given to the blood supply to the epiphysis of the femoral head The findings are discussed in relationship to those of others The deep branch of the medial circumflex artery terminated as the lateral arteries to the epiphysis With increasing age these latter arteries were found to be of increasing importance with regard to the blood supply of the epiphysis The *artery in the round ligament of the femoral head* was found to have little if any *importance to the* epiphysial blood supply in children

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DISCUSSION

In the macroscopic part of this investigation it is made clear that the RP is tightened over the tendon of the external obturator muscle when the hip is extended and even more if it is rotated inwardly too According to arteriographic investigation (Mussbichler 1970) great individual variation in the course of the RP exists Supposing the artery in some cases is placed deep to the tendon it will then be compressed between the tendon and the capsule in the extended position of the hip, for example in normal standing Among the hips in the present study no such case was found, but this supposed deep localization might explain the findings of Hipp (1962) who observed closure of the RP in patients with Perthes' disease.

As to the microscopic part of the investigation the results are admittedly defective due to technical reasons in particular The results are primarily dependent on successful removal of the blood from the vessels followed by complete filling of the arteries with injected material

Of the 12 hips, eight have been sufficiently prepared to give some evidence about the position and relationship of the arteries to the upper end of the femur This small material obtained from children aged four months to 11 years is hardly representative enough to draw general conclusions but it can be compared with other investigations Preparing the upper femoral end in one whole block gives the advantage of not destroying any of the arteries This will happen when the blocks are sawn into halves or slices With this technique the total block can be placed in any position while studying the arteries from different angles under the microscope As a whole block all diffusion to and from the epiphysis has to pass the cartilage and this will prolong the time needed to decalcify and prepare the blocks In these larger blocks it is impossible to study the finer structure of the vessels inside the bone as Trueta & Morgan did in 1960 in a study of the vascular contribution to osteogenesis

In general this investigation has confirmed the findings made by other investigators In a child of four months not as many small arteries to the epiphysis were found as by Trueta (1957) and Crock (1967) In the youngest children the anastomoses between the networks in the fovea and the epiphysis did not follow exactly the same pattern as in the investigation of Trueta These anastomoses were found at the age of three but not at the age of nearly ten in the present study Trueta found the lateral epiphysial arteries (RNCP) to be the only

arterial supply to the epiphysis after the age of six years whereas in this study a medial retinacular artery (RNCD) was found passing to the epiphysis at the age of nearly 10 years This study agrees with Wolcott (1943) and Tucker (1949) in that the vessels in the round ligament of the head (ALCF) *primarily supply connective tissue in the* fovea and have little importance for vascularization of the epiphysis In the present preparations the anterior retinacular arteries (RNCA) passed more constantly to the epiphysis than reported by other investigators *It is the author's opinion that the lateral, the distal and* the anterior retinacular arteries *(RNCP RNCD and RNCA) belong to* the synovial network which is more clearly seen with increasing age Possibly this is what Harty (1953, 1966) described as two ring anastomoses The retinacular arteries arise from this synovial network and follow it to the border of the cartilage from whence they continue along the border between metaphysial bone and surface cartilage giving off branches into the metaphysial bone before entering the epiphysis as they pass obliquely through the edge of the epiphysial cartilage *The lateral arteries (RNCP) become increasingly dominant* in the blood supply to the epiphysis with increasing age If the blood supply through these arteries is stopped the epiphysis will undergo ischaemia especially in children more than 5-6 years of age This condition persists until the rest of the smaller arteries have grown sufficiently *to compensate*

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A method used to inject Microphil® into the arteries of the hip region in children of various ages at autopsy is described By macroscopic dissection and microscopic investigation particular attention was given to the blood supply to the *epiphysis of the femoral head* The findings are discussed in relationship to those of others The deep branch of the medial circumflex artery *terminated* as the lateral arteries to the epiphysis With increasing age these latter arteries were found to be of increasing importance with regard to the blood supply of the epiphysis The artery in the round ligament of the femoral head was found to have little if any importance to the epiphysial blood supply in children

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BLOOD METHYL METHACRYLATE LEVELS IN PATIENTS HAVING PROSTHETIC JOINT REPLACEMENT

K Pahuja, H Lowe & K Chand

Accepted 9 ii 74

Much of the orthopedic reconstructive surgery of joint replacement has been made possible by fixation of prosthetic components, both polyethylene and metallic, by polymeric methyl methacrylate cement The results of this reconstructive surgery are very gratifying indeed (Charnley 1970, McKee & Farrar 1966, Owen 1972) At least 28 cases of cardiac arrest following the use of methyl methacrylate cement in the fixation of the prosthetic components have been reported (Charnley 1970, Gresham 1971, Kepes 1972, Phillip 1970, Powell et al 1970, Schulitz et al 1971, Thomas 1971) This has led to the speculation that monomeric methyl methacrylate (MMA) absorbed from the "cement mix inserted in the vascular marrow cavities of the major bones may be a major contributory factor in the mortality and morbidity of these patients

METHODS AND MATERIALS

Simplex P was used in our patients The specific formulations are proprietary but the basic components can be deduced from literature on this polymer system Charnley 1970 Skinner & Phillips 1967) The powder consists primarily of poly methyl methacrylate polymer and less than 1 per cent by weight catalyst (benzoyl peroxide) The liquid portion is primarily methyl methacrylate monomer including perhaps small amounts of difunctional monomer such as ethylene dimethacrylate, an accelerator such as NN dimethylparatoluidine (NNDPT) and a stabilizer such as hydroquinone When polymeric powder is mixed with monomeric liquid, polymerization occurs the monomer being activated by benzoyl peroxide and the mixture changes from a paste to a solid Some of the monomer evaporates and some is absorbed in the systemic circulation The amount of monomer absorbed is much more if the mix is inserted as a paste rather than when it is in "dough" form About 80 per cent of the available monomer is polymerized in the first minute after mixing

In the 34 patients being reported here full preoperative evaluation especially for pulmonary and cardiovascular status was done During surgery patients were

continuously monitored for any changes in arterial blood pressure, pulse, EKG and blood gases Full replacement of lost blood by whole blood was made before the insertion of cement as the hypovolemic patient is more sensitive to the effects of MMA Sufficient monomer was released from the surface of the "mix" by exposure to atmosphere (Charnley 1970) When this was not done, the MMA blood levels were very high (*vide infra*) Usually about 20 per cent of the cement mix (40 g of polymer and 20 ml of liquid monomer) was used in the acetabulum and 80 per cent of cement mix was used in the femur in total hip procedures In total knee replacements of the Shier and Walldius type a separate packet was used for the femur and the tibia In total knee prostheses of the geometric and polycenteric types about 50 per cent of each packet mix was used for the femur and the tibia respectively An attempt was made to make the acetabular and femoral beds as dry as possible both for better adhesion of the "cement" and also to decrease absorption of monomer from the bed A vent was used in femoral and tibial marrow cavities as an outlet for blood, marrow and liquid monomer Patients were handled gently so as to reduce any adverse effect on their cardiovascular status

Mixed venous blood samples were obtained from a central venous line prior to surgery and at 2 minute intervals following insertion of the cement in the bone cavity In the total knee replacements blood was also withdrawn following release of the tourniquet Samples were analyzed immediately by injecting one microliter directly into the injection port of a flame ionization detector (F & M Model 1609) The chromatograph was standardized with a water solution containing 9 4 mg of MMA/100 ml

RESULTS

Thirty-four consecutive patients who underwent 38 procedures were studied Most of these patients also had associated cardiovascular and pulmonary pathologies and were in their fifth or higher decade MMA levels varied from a trace to 200 mg per cent (Table 1)

In total hip series, no MMA was detected for up to 4 samples (8 minutes) following insertion of cement in the acetabulum When cement was inserted in the femur, MMA was detected in 5 out of 23 procedures The levels were very low in 3 patients, 1 1 mg per cent in one patient and very high (200 mg) in another patient, where the cement was inserted in a comparatively fluid state In this patient the arterial PO_2 decreased from 103 torr to 80 torr when cement was inserted In the postoperative period, she had paralytic ileus with pulmonary hypoxia and chest pain There were no petechiae

In the series of fractures of the neck of the femur, MMA was detected in one patient out of four, where the level was 0 6 mg per cent

In the total knee replacement series, MMA was detected in 2 patients out of 5, when the hinged type prosthesis (Walldius or Shiers) was

used The stems of these prostheses are fairly long and required one pack each for the femur and the tibia MMA was detected during tourniquet inflation but was not detectable after release of the tourniquet This absorption of MMA may be due to uninterrupted marrow circulation In the non hinged variety (Geometric and Polycentric) where a small amount of cement is used MMA was detected (1 7 mg/100 ml) in one patient with a geometric knee at the time of the tibial component insertion

Table 1

38 procedures (34 patients)		No of procedures in which MMA was present in blood	Levels of MMA
Total h p replacement	23	5	0 016, 0 19 0 12 1 1 200 mg%
Total knee replacement			
Shiers	3	1	0 32 mg% (decreasing levels up to 5 samples)
Walldius	2	1	Trace
Geometric	4	1	1 7 (Decreasing levels up to 4 samples)
Polycentric	1	0	0
Kuntscher nailing for metastatic fracture	1	0	0
Fracture neck femur (A Moore & Thompson prosthesis)	4	1	0 f mg%

DISCUSSION

The levels of MMA observed in venous blood agree with those reported by other investigators (Bloch et al 1970 Homsy et al 1972) Bright (1972) quotes figures of 1 mg/100 ml studied by flame ionization gas chromatography Homsy et al (1972) using C14 MMA in a series of 6 patients found MMA in 4 patients with the highest level of 1 25 mg/100 ml in inferior vena caval blood Bloch et al (1970) found MMA in 10 per cent of the procedures at levels of 1 2 mg per cent and in one sample the level was 10 mg per cent Kim et al (1972) reports 1 1 mg/100 ml as the highest level in 4 out of 10 cases These levels are much less than toxic levels reported in animals though the levels at which pulmonary lesions occur in humans is not known Intravenous

administration of MMA in canines causes local pulmonary hemorrhages at levels as low as 5 mg/100 ml, though no long term morbidity was seen even at levels of 50 mg/100 ml (Homsy et al 1972) In one of our patients, the MMA level was 200 mg and she had pulmonary hypoxia during surgery and the postoperative period Aeration of cement would have reduced the absorption of MMA

MMA rapidly disappears from the blood stored in the syringe By the time the 4th to 6th samples were analyzed, no MMA could be detected. This does not mean that MMA was not present in these samples at the time of withdrawal, but it could be due either to absence of MMA in blood withdrawn at the time or rapid metabolism of MMA in blood in the syringe. In studies by Homsy et al (1972) MMA was not detectable in venous blood 20 minutes after implantation of cement in canine femora

The LD_{50} dosages for intraperitoneal, subcutaneous and oral exposures to MMA in guinea pigs are 2 0, 6 3 and 6 3 ml/kg respectively (Spealman 1945) In dogs the LD_{50} dosages for oral and subcutaneous routes are 5 0 and 4 5 ml/kg (Spealman 1945) In Homsy et al 's (1972) experiments in dogs, death occurred when blood levels of MMA were 125 mg/100 ml following intravenous administration of MMA Pulmonary pathology in dogs varies from hemorrhages to respiratory arrest with progressively higher doses These high levels are uncommon in humans, but if proper precautions are not taken, fairly high levels of 200 mg/100 ml can be reached in humans These high concentrations are invariably associated with complications in patients with poor cardiovascular and pulmonary functions

SUMMARY

Monomeric Methyl Methacrylate (MMA) was measured from mixed venous blood of 34 patients undergoing hip and knee reconstructive surgery One microliter of blood was injected into the F & M hydrogen flame ionization chromatograph (Model 1609) and compared against an H_2O standard Monomer was detected in 9 patients The levels varied from traces to 200 mg per cent In the patient with the high level of 200 mg per cent, the cement was inserted before it was in dough form, and the patient's morbidity in the early postoperative course was marked

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Figure 1



Figures 1 and 2 The prosthesis after the initial operation shows a normal position



Figure 2

left leg with impaired movement of the hip Radiographs revealed dislocation of the prosthesis (*Figure 3*) This dislocation had probably occurred during the previous night when the patient had experienced some chest pain and rapidly turned into her right side in an attempt to sit up Her exact movements could not be elucidated retrospectively but there was probably sudden flexion and adduction of the left hip She felt that "something happened" in the hip but was too pre-

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DISLOCATION OF A TOTAL HIP PROSTHESIS OF THE CHRISTIANSEN TYPE

A Case Report

OLOF AHLGREN & RUDOLF LEMPERG

Accepted 29 iii 74

The trunnion-bearing hip prosthesis was devised by Christiansen (1969), and Ramstad (1969) reported good results after two years of practical experience with this prosthesis. A similar prosthesis was also designed by Weber (1970). An advantageous feature of this type of prosthesis is that, after insertion of the acetabular and femoral components, optimal tightness of reduction may be obtained by the use of interchangeable lengths of the head and neck component. This feature may be useful during hip replacement in patients with long standing contractures of the hip.

CASE REPORT

A 60 year old housewife developed avascular necrosis of the femoral head two years after a medial fracture of the neck of the left femur. In 1967 a fixed adduction deformity of 30° was found and treated by an adductor tenotomy. The patient remained relatively symptom free during the following five years. In 1972 she developed increasing pain. Examination of the hip revealed fixed adduction and flexion deformities of approximately 30°. Prosthetic replacement of the hip was therefore advised. The patient gave a history of angina pectoris but had a normal electrocardiogram.

Prosthetic replacement of the left hip was performed by a senior resident through a posterior approach as routinely used in this department. The Christiansen type of prosthesis was chosen because of the long standing contractures of the hip. The operation was performed without any technical difficulties and resulted in a full range of hip movement. Post operative radiographs showed a good position of the prosthesis (Figures 1 and 2). The patient was mobilized post operatively by standing out of bed on the second day after operation and walking without weight bearing on the fourth day. There was an ordinary range of movement in the hip and normal subjective complaints during mobilization.

Six days after the operation the patient was found to have a shortening of the

Figure 1



Figures 1 and 2 The prosthesis after the initial operation shows a normal position



Figure 2

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Figure 3 After luxation the head component of the prosthesis is dislocated dorsally

occupied by her heart to mention this to nursing staff during the night After three weeks an open reduction of the hip was performed and the head component of the prosthesis was reinserted on the stem No surgical reason for the luxation could be found The delay in this operation was due to a myocardial infarction

COMMENTS

Ramstad (1969) mentioned one dislocation of a Christiansen prosthesis, but no details of the type of dislocation were given Dislocation of the femoral head in relation to the stem is a serious complication, as reduction by conservative means is impossible and a further operation has to be performed This is, in our opinion, a clear disadvantage of this type of prosthesis and should be taken into account when choosing the type of prosthesis for hip replacement

SUMMARY

Luxation of a trunnion-bearing type of hip prosthesis (Christiansen model) with dislocation of the head in relation to the stem of the prosthesis is described Reposition by conservative means is impossible and open reduction is the only feasible treatment

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TRAUMATIC DISLOCATION OF THE HIP IN CHILDREN

Report of Two Cases

L HOVELIUS

Accepted 8 ii 74

Traumatic dislocation of the hip is very rare in children (Blount 1955) A material of 59 cases, most of them from the literature, was reported by Choyce in 1924 and about 350 cases have been published since then (Pearson & Mann 1973) but there are still not enough examples to yield definite percentages for the incidence of complications and so on (Freeman 1961) By circularizing 340 British orthopedists and adding 5 cases of their own, Glass & Powell (1961) collected 47 cases with an observation time of more than six months In the Scandinavian literature, 76 traumatic hip dislocations have been described by Paus (1951), 19 of them in children It is unusual for the dislocation to recur A case with two recurrences has been reported by Gaul (1973), who was able to find only 12 other definite cases of this type in the literature

Of the two cases presented here, case 1 was treated at this hospital and case 2, which recurred once, received primary treatment at another hospital

CASE REPORTS

Case 1

A 3 year old boy who knocked his right hip while riding on a tea tray in the snow Examination at this hospital the same day revealed impaired mobility in the hip The patient lay with a slightly shortened flexed leg with some inward rotation X rays revealed backward dislocation (Figure 1 a and b) and reduction was easily performed under anesthesia After two days in bed the patient was mobilized with a full load on the injured leg An examination more than 1½ years after the injury showed no subjective complaints and an entirely normal clinical and radiographic picture

Case 2

A boy, now 14 years old who fell while skiing at the age of 12 and knocked his right hip He was admitted to the local hospital the same day and X rays showed



Figure 1 a. Case 1 Frontal projection showing right sided luxatio coxae



Figure 1 b Case 1 With the hip rotated forwards the neck of the femur projects laterally indicating posterior dislocation

backward and upward dislocation of caput femoris (*Figure 2*) Reduction under anesthesia caused no difficulty and the patient was kept in bed for 3 weeks Nothing of note was observed during a walking test at a check up after 1½ months

Less than 3 months after the first dislocation the patient was tripped up and fell directly on the right hip The resultant dislocation proved less easy to reduce



Figure 2 Case 2 Right-sided hip dislocation after the first accident



Figure 3 Case 2 Two years after the second accident the neck of the right femur has clearly increased its size compared with the left

because the head of the femur tended to dislocate once more Traction was therefore applied to the tibia for 5 weeks The position of caput femoris appeared satisfactory in X rays taken after this reduction but tomography revealed a small posterior acetabular fragment A further radiographic examination about 1 month after the patient had been mobilized indicated latero proximal subluxation of caput femoris

At an examination 2 years after the second accident the patient reported slight discomfort in the hip in the form of pain after a great deal of physical exercise Hip mobility called for no comment Trendelenburg's sign was not present and the patient did not limp X rays showed status quo regarding the position of caput femoris and the acetabular fragment had healed in well The head and, in particular the neck of the femur on the injured side displayed greatly increased growth the neck being 10 mm wider than on the left side (Figure 3) There were no signs of caput necrosis and no indication in the upright position of cartilage reduction

DISCUSSION

Traumatic dislocation of the hip is relatively common among adults but rather rare in children In many young patients the cause may be a trivial trauma (Glass & Powell 1961)

Hip dislocations are divided anatomically into posterior and anterior In a review of traumatic dislocations in adults, Lamke (1970) found 102 posterior and 8 anterior In children, however, it seems that the dislocation is almost always posterior (Freeman 1961, Glass & Powell 1961 and Schlonsky & Miller 1973)

There is general agreement about the immediate treatment of these dislocations—reduction as soon as possible under anesthesia—but opinions differ somewhat as to the manner and duration of immobilization A hip cast for 4 6 weeks and no loading for the first 2–3 months are recommended by Freeman, whereas Schlonsky & Miller as well as Pearson & Mann hold that early loading does not appear to increase the number of complications Lamke found that in adults the injured hip could be loaded after only 2 weeks

The most likely complication is caput necrosis In the 47 cases collected by Glass & Powell, avascular caput necrosis was noted in 4, arthrotic changes in 3, premature epiphyseal ossification in 1 and caput enlargement in 6 They found no other mention of the last of these changes neither has it been reported more recently after hip dislocation

The chief predisposing factor for complications is held by Glass & Powell to be age, because the avascular and arthrotic changes in particular usually followed dislocation in persons who were more than 10 years old In adults the incidence of caput necrosis after dislocation is variously reported to be between 5 and 30 per cent Lamke found 8 cases of necrosis among 110 dislocations

As already mentioned relatively few cases of re-dislocation have been reported in children (Gaul 1973) Other cases have been published

which are not included in Gaul's review (Body 1969, Masse & Florent 1964, Gula 1972) Re-dislocation occurred twice in Gaul's own case even though a primary hip cast had been applied for 6 weeks Subsequent surgery revealed that the posterior part of the capsule had broken away from the acetabular margin and a synovial pocket had formed The edges of the capsule were re-adapted and there was no further recurrence Similar findings at surgery for recurrent traumatic dislocation in children have been described by, for instance, Aufranc et al (1964) and Body (1969)

Symptoms of complications generally occur within 10 months (Freeman), though avascular necrosis may develop as much as 3 years after the accident (Pearson & Mann)

SUMMARY

Two cases of traumatic hip dislocation in children are presented In one of these, a moderate trauma caused re dislocation after 3 months This type of dislocation is unusual The younger the child, the slighter the trauma which may lead to dislocation, which is of the posterior type as a rule The treatment is closed reduction under anesthesia with immobilization, which probably need not last longer than a few days up to a week Complications are caput necrosis, osteoarthrosis, possibly an increased growth of the head or neck of the femur, and re-dislocation Recurrent dislocation may have to be treated surgically, in which case it is recommended that the posterior part of the joint capsule is narrowed

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RADIOGRAPHIC DETERMINATION OF CARTILAGE HEIGHT IN THE KNEE JOINT

TAGE MARKLUND & RUNE MYRNERTS

Accepted 16 xi 73

In the radiographic determination of the cartilage height in the knee joint it is conventional to expose the film with the patient in the standing position The condyles are then pressed together and the width of the articular space may be assumed to represent the true height of the cartilage This has been demonstrated by Ahlbäck (1968) Even in this posture, however, a reduction in the height of the cartilage in the femorotibial joint may escape detection Ahlback found that in a patient with advanced gonarthrosis (osteoarthritis of the knee joint) the width of the articular space can diminish after a few minutes' walking (prolonged weightbearing) The explanation this author advanced for this is that the irregular surfaces of the cartilage become better adapted to one another The same author reports cases where a reduction in the height of the cartilage in the knee joint was not seen until the knee was flexed, or the flexed knee was forcibly abducted

The study reported in this article was undertaken with the object of examining the significance of flexion of the knee joint for determining the height of the cartilage

MATERIAL AND METHOD

The case series for the study comprised a group of patients with normal or fairly normal, width of the articular space and more or less advanced skeletal changes in the form of sclerosis cysts and osteophytes Despite well defined secondary skeletal alterations there was remarkably little reduction in the height of the cartilage as seen with the patient in the standing position and the leg extended These patients were submitted to another examination also in the standing position, but now with the knee joint flexed to give an angle of about 170° In some of the patients both knees were examined and the series therefore includes a number of joints with only minor skeletal changes, if any The material comprised 30 knees in 19 patients



Figure 1 a Knees in hyperextension



Figure 1 b Knees without hyperextension



Figure 1 c Knees slightly flexed

Figure 1 *Patient with pronounced skeletal alterations in the left knee (in standing position)*

RESULTS

No *skeletal alterations* were seen in 10 of the knee joints, and the width of the articular space was normal when the knee was extended and when it was flexed

Minimal osteophytes were observed in 5 knee joints and they were located on the border of the articular surface The width of the articular space in the standing position with the knee *extended* was normal

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that part of the femoral condyles, which articulates with the tibia when the knee is slightly flexed Still the height of the cartilage of the part of the femoral condyles that articulates with the tibia on hyperextension of the knee may be normal In spite of the fairly small change in the angle of flexion from hyperextension to about 170°, the articular space was diminished greatly in several of the patients—*from* 5 *to* 0 *mm* The variability of the space sometimes recorded on repeated examination in the standing position may thus be ascribed to quite small differences in the angle of flexion of the knee joint The change in the width of the articular space observed in some patients after walking for a time may have the same explanation

SUMMARY

The reduction in the height of the cartilage in the knee joint can often be seen only on films exposed with the patient standing with the knees slightly flexed A 10° angle is sufficient

The width of the articular space with the knee extended or hyperextended may be due to the cartilage on the anterior part of the femoral condyle To obtain a more reliable estimate of the reduction in the height of the cartilage in the femorotibial joint the examination should be carried out with the patient standing with slightly flexed knees

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2 a Knee in hyperextension

2 b Knee slightly flexed

Figure 2 Patient with pronounced skeletal alterations (in standing position)

in all the patients With the knee *flexed* the width was normal in all but one patient, where it was slightly reduced

Pronounced skeletal alterations were recorded in 15 knee joints Examined in the standing position with the knee *extended* all the articular spaces were normal, or practically so When the knee joint was *flexed* to give an angle of 170° the articular space was completely obliterated in 5 patients (Figure 1 a b c), reduced to about half its earlier size in 2 (Figure 2 a, b), and diminished slightly in 5 patients In 3 patients there was no evident difference from the former width

CONCLUSION

In the standing position a reduction in the cartilage in the knee joint is more likely to be seen if the X ray examination is conducted with the knee flexed than if it is extended

DISCUSSION

The reduction in the width of the articular space on flexion of the knee is most likely due to a change in the thickness of the *cartilage of the* femoral condyle *In gonarthrosis* this reduction is probably greatest on

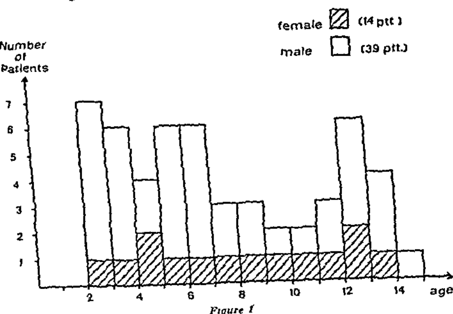


Figure 1

"right legged" (preferring the right leg in strength and precision achievements) and 5 "left-legged"

Table 1 Type and level of fracture in the 53 patients

Type	No of patients
Short oblique	6
Long oblique	22
Transverse	14
Comminuted	11
Level	
Upper third	13
Middle third	36
Lower third	4

Treatment

All 53 patients had primarily been treated by traction (52 by plaster traction and one by skeletal traction on the tibial tuberosity) In four cases the treatment was later supplemented by plaster casts. One week after application of the traction six patients were treated by open reduction and osteosynthesis, four by Parham's

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QUADRICEPS FUNCTION FOLLOWING FRACTURES OF THE FEMORAL SHAFT IN CHILDREN

V. Damholt & D. Zdravkovic

Accepted 14 xii 73

It is generally agreed that in children conservative treatment is preferable to operative treatment of fractures affecting the femoral shaft Serious complications are rare (Barfod & Kristensen 1958, Burwell 1969). In assessing late results particular interest has been displayed in the growth accelerations (with subsequent disparity of limb length) (Guldhammer 1963). In the endeavour to contribute to further objective parameters, we investigated quadriceps function by measurements of its isometric strength and dynamic endurance in patients with a history of such fractures during childhood

MATERIAL

The material is derived from the Odense University Hospital, 1955–1967, and comprises children aged 0–15 years with fracture of the femoral shaft without other associated fractures or injuries to vessels or nerves In addition, the material was selected so as to be of an approximately equal distribution in the age groups 0–4, 5–9, and 10–14 years Records were collected from 1955 onwards The collected records were divided into three pools which were closed when each comprised 20 patients Thus, each pool had an age range of five years The minimum follow up period was 2 years and the earliest age at follow up was 15 years Fractures of the femoral shaft were taken to be all fractures located from the inferior edge of the lesser trochanter down to 2 cm above the distal epiphyseal line Of the 60 patients selected 57 attended follow-up Among these 57 patients four had to be excluded as one suffered from severe intellectual impairment, one had patellar chondromalacia, one sequelae to numerous ankle distortions, and one clinical signs of marked asymmetry of the muscles in the right and left lower limb

Figure 1 gives the age distribution and sex ratio. The age distribution is fairly equal, but no patient was between 0 and 2 years The ratio girl/boy was one/three Table 1 presents the level and type of fracture (according to Dencker 1963) Only two patients had open fractures The two sides were equally affected, 27 fractures being on the right and 25 on the left side Forty-eight patients reported being

the unaffected leg Table 4 sets out differences in circumference exceeding 2 cm as compared with the unaffected leg, measured 15 and 8 cm above the patella The circumference of the affected leg was on an average 0.5 cm less that that of the contralateral leg This difference is significant (T paired test = 3.50, d.f. = 52, $P < 0.001$)

Table 4 Difference in circumference of more than 2 cm 15 and 8 cm above the patella on the affected limb as compared with the unaffected one

Level above patella	No of patients	
	Decrease in circumference	Increase in circumference
15 cm	9	1
8 cm	3	1

Table 5 Percentage difference in isometric strength and dynamic endurance

	Percentage difference	No of patients	
		Isometric	Dynamic
Affected leg stronger	≥ 20.1	1	2
	20.0–10.1	2	4
	10.0–0.1	11	4
No difference	0.0	4	6
Unaffected leg stronger	0.1–10.0	19	9
	10.1–20.0	8	11
	≥ 20.1	8	17

Table 6 T testing of the results of strength measurements in relation to age (T paired test)

Patients age in years	0–4	5–9	10–14
No of patients	15	23	15
Isometric	T=1.59 d.f. 14 $P > 0.05$	T=1.05 d.f. 22 $P > 0.05$	T=3.04 d.f. 14 $P < 0.01$
Dynamic	T=2.97 d.f. 14 $P < 0.05$	T=2.00 d.f. 22 $P > 0.05$	T=4.39 d.f. 14 $P < 0.001$

band, one by a Lane plate, and one by a single screw. The duration of traction and the time of mobilization are shown in Tables 2 and 3. Most patients were out of bed 4–8 weeks after the accident. None were subjected to a special physical therapy training programme. Two patients had brief, superficial infection. One of them had been treated by a Lane plate and the other one by a single screw. None had developed osteitis. In the remaining 51 patients no complications occurred.

Table 2. Duration of traction

Duration in days	No. of patients
≦ 28	17
29–42	30
≧ 43	6

Table 3. Duration of bed rest

Duration in days	No. of patients
≦ 28	0
29–42	27
43–56	13
≧ 57	13

METHOD

At follow-up all femora were X-rayed. Measurements were made of the circumference of the thigh 8 and 15 cm above the patella, the length of the lower leg from the knee line to the tuberosity of the calcaneus, as well as of the isometric strength and dynamic endurance according to a method described previously (Damholt & Zdravkovic 1972).

RESULTS

All the patients seen at follow-up were free of pain and had full extension as well as flexion of at least 120° at the knee. Four had complaints in the form of fatigability in the affected limb. One had 20° medial and 15° dorsal angulation, one had 10° ventral and one 10° medial angulation of the distal fragment. Fifteen exhibited a 0.2 cm lengthening of the affected leg and two patients 1 and 2 cm shortening respectively. One of those patients had undergone epiphysiodesis on

Comparison of the strength measurements in the affected and unaffected leg in 33 patients (Table 7) in whom the affected leg was simultaneously the "preferred" leg showed no difference in isometric strength (T paired test 1 87, d f 32, $P > 0.05$), but a significant reduction of dynamic endurance on the affected side (T-paired test 3 14, d f 32, $P < 0.01$)

DISCUSSION

The literature is very sparse with respect to elucidating muscle function following fractures of the limbs, and this function is rarely used as a criterion for assessing the therapeutic results particularly in children The status of the muscles after femoral fractures has often been evaluated by measurements of circumference, but direct measurements of quadriceps function have not been carried out In a previous study (Damholt & Zdravkovic 1972) a significant reduction in isometric as well as in dynamic strength on the fractured side was found in two-thirds of adult patients, and Hecbol Nielsen (1964) has found abnormal weakness (exceeding 15 per cent) in a similar material In children there was a significant reduction of strength and abnormal weakness in more than one-third However, the materials are not comparable, as the severity of the fractures differed when assessed by comminution (in about half the adults and only one-fifth of the children) and as the routine treatment of the adults was by osteosynthesis giving direct access to the fracture, whereas practically all the children were treated conservatively The reduction in dynamic endurance was more marked than that of isometric strength, and this finding is in accordance with previous studies Reduction of strength proved to be most pronounced in children of the oldest age group Measuring the circumference in assessing the muscle status on the fractured leg seems to be of limited value, as it was correlated only with dynamic endurance, whereas in the unaffected leg it was correlated with both measurements Also, it was not possible to demonstrate a consistently better muscle strength in the group where the affected leg was also the preferred leg There was no definite relationship between the results of the dynamic and isometric measurements, most patients having mild reduction of isometric strength and pronounced reduction of dynamic endurance in the affected leg That selective training of one muscle function need not necessarily entail changes of other muscle functions has also been demonstrated in

Table 7 Percentage difference in isometric strength and dynamic endurance in the 33 patients whose affected leg was also the preferred leg

	Percentage difference	No of patients	
		Isometric	Dynamic
Affected leg stronger	≧ 20 1	1	2
	20 0–10 1	3	3
	10 0– 0 1	7	3
No difference	0 0	3	1
Unaffected leg stronger	0 1–10 0	11	6
	10 1–20 0	4	8
	≧ 20 1	4	10

Table 5 presents the percentage difference between the strength of the affected and the unaffected leg Measurements of isometric strength showed the fractured leg to be stronger than the contralateral leg in 14 patients In four cases there was no difference Thirty-five of the fifty-three patients had reduced strength of the affected leg, with a maximum reduction of 36 8 per cent, mean 12 9 per cent The results of measuring dynamic endurance are also listed in Table 5 In 10 cases the affected leg was stronger than the unaffected one In 6 cases there was no difference The remaining 37 patients showed a reduction of dynamic endurance in the affected leg, maximum 45 per cent, mean 19 5 per cent This reduction in endurance was significant (isometric strength T-paired test 3 18, d f 52, $P < 0\ 01$ dynamic endurance T-paired test 4 43, d f 52, $P < 0\ 001$) From Table 6 it is apparent that only the oldest group exhibited a significant reduction of isometric strength and dynamic endurance in the affected leg The measurements in the four patients whose fractures had affected the distal third of the femur did not differ from those in the group as a whole

An investigation was made to detect a correlation between circumference and strength of the affected and unaffected leg In the case of the unaffected leg there was a significant correlation between circumference and both measurements of strength (isometric strength $r = 0\ 50$, $P < 0\ 001$, dynamic endurance $r = 0\ 34$, $P < 0\ 05$) In the case of the affected leg there was no significant correlation between circumference and isometric strength ($r = 0\ 23$, $P < 0\ 05$), but between circumference and dynamic endurance ($r = 0\ 27$, $P < 0\ 05$)

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previous studies on patients with fracture of the femur (Damholt & Zdravkovic 1972) and in normal subjects (Hansen 1967)

A previous study by the present authors (Damholt & Zdravkovic 1972) revealed a tendency to greater reduction of strength the more distally the fracture was located. The level of fractures in children is characterized by a low percentage in the distal third of the femur (Barfod & Kristensen 1958, Burwell 1969) Our material included only four patients having fractures in this site, and they did not differ from the series as a whole

SUMMARY

Fifty-three selected patients, treated in the Odense University Hospital for femoral fractures in childhood during the period 1955 to 1967, were investigated for quadriceps function by measurements of isometric strength and dynamic endurance Forty-seven had been treated conservatively, the remaining 6 by osteosynthesis Isometric as well as dynamic measurements revealed a significant reduction of strength in the affected leg Measuring the circumference of the fractured leg to assess its muscle status appears to be of limited value when correlated only to dynamic endurance, whereas in the unaffected leg it was correlated to both measurements Moreover, it was not possible to demonstrate consistently greater muscle strength in the group in which the affected leg was also the preferred leg

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MATERIAL AND METHOD

For investigation of the movement of the l Bl during knee flection we used the lateral radiographs of 5 healthy subjects obtained in full knee joint extension and in increasing flection up to 110 degrees (the 70 degree position) The radiographs were made with intervals of 15 degrees

The movements of the l Bl and the apex patellae are both analysed in relation to the tibia which thus can be regarded as the fixed part The outline of the tibia is drawn on a translucent template placed on the first radiograph and so is the l Bl and the apex patellae This template is placed successively on the following radiographs of the same subject and both the l Bl and the apex patellae are marked for each new position while the outline of the tibia on the template is brought to cover the outline on the radiograph Figure 1 is the result of this procedure

The 5 normal subjects satisfy the same clinical and radiological demands as the subjects in our previous work.

Alterations in the angle v caused by alterations in the position of the knee in the X ray beam were investigated on 10 human knee specimens. These were fastened to a stake in the centre of a rotatable disc with a degree scale in a circle around the disc A pointer showed the rotation from the zero or neutral position In this position the direction of the X ray beam was at right angles to the specimen from the tibial or fibular side The joint was in 90 degrees of flection The zero or neutral position was defined as the one where the distal outlines of the two femoral condyles were tangentially hit by the same beam which means they were projected onto each other on the radiograph After exposure in this position radiographs were taken with 5 10 15 30 and 45 degrees of rotation, both inwards and outwards

RESULTS

Figure 1 has the same appearance in all the 5 investigated cases The distance a at 30 degrees of knee flection is in these cases 22 mm on the average ranging from 15 to 26 mm At an alteration of the flection from 30 degrees to 45 degrees the reduction of a is, on the average, 14 mm (ranging from 9 to 18 mm) while the reduction of a at an alteration from 15 degrees to 30 degrees of flection averages 11 mm (ranging from 9 to 12 mm) So, the reduction of a is less from 15 to 30 degrees of flection than it is from 30 to 45 degrees

The point of intersection between the l Bl and the apex patellae among these subjects occurs at an average of 52 degrees of knee flection

The alterations of the angle v during rotation of the object in an X ray beam of constant direction are given in Table 1 The variation of v in each specimen during rotation from the neutral position to a position of 45 degrees rotation, both outwards and inwards, ranges

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CHARACTERISTICS OF THE LINE OF BLUMENSAAT

An Experimental Analysis

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Accepted 11 i 74

The line of Blumensaat, l Bl, is a faint condensed line on the lateral radiograph of the knee joint in the condylar massif of the femur It represents the tangentially hit part of the roof in the intercondylar fossa This line has gained its special interest from the fact that Blumensaat (1938) used it as a landmark for the vertical location of the patella at a knee flection of about 30 degrees, the normally located patella will touch the extension of the l Bl

In a previous paper we have stated (Jacobsen & Bertheussen 1974) that this definition is untenable, as the vertical location of the normal patella is considerably higher than suggested by Blumensaat We have also called attention to the fact that the relation to the l Bl is a poor measure for the location of the patella as, during knee flection, this line shows a marked alteration of its direction The perpendicular distance, *a*, from the apex patellae to the l Bl is thus much more dependent on the degree of knee flection than on the length of the patellar tendon A more thorough analysis of the complicated movement of the l Bl is carried out in the present paper

Another characteristic of the l Bl is the formation of an angle, *v*, between the line and the axis of the femoral shaft In our previous work we found this angle to be 32 6 degrees on the average, with a small dispersion, while Brattstrom (1970) found a mean value of 45 degrees and a dispersion of from 27 to 60 degrees An investigation of this matter is also carried out in the present paper

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Aided by a grant from the Danish Medical Research Council

Table 1 The variation of the angle v during rotation of the knee in a constantly directed X-ray beam

Position (rotation) degrees	Angle v (degrees)	
	Mean	Range
0	33	30–38
15 outwards	35	31–42
30 outwards	37	32–47
45 outwards	39	32–50
15 inwards	36	29–41
30 inwards	39	33–46
45 inwards	42	31–55
Total variation		29–55

knee flection is caused by alterations in the tension of the patellar tendon The latter is slack in the extended knee and in small degrees of flection, when the leg is supported as it is during the procedure of radiography At about 30 degrees of flection the tendon is taut, and the subsequent movement of the apex patellae takes place along an arc of a circle, whose centre is the insertion of the patellar tendon on the tuberosity of the tibia and whose radius is the tendon The posterior part of the circle movement is made possible by the diminishing radius of the sliding surface on the femoral condyles (see below), which draws the condyles and also the L Bl backwards in relation to the tibia The described movement of the apex patellae is almost vertical during the first part of the knee flection, which means that the apex is withdrawn from the approaching L Bl This explains the previously mentioned fact that the reduction of a is less in the beginning of the knee flection, from 15 to 30 degrees, than it is in the interval from 30 to 45 degrees It is apparent that the point of intersection between the L Bl and the apex patellae occurs at a little more than 45 degrees of knee flection, considerably above the level suggested by Blumensaat

The movement of the L Bl as it is shown here is in agreement with the classic "mechanics of the joints", as stated by Fick (1904–11) Our interest lies especially in the intermingled rolling and sliding of the femoral condyles on the tibia during knee flection The analysis of this movement was originally carried out by Fischer (1907), by means of Zuppinger's lateral radiographs of the knee during flection (1904) Figure 2 (Fischer) explains this movement The corresponding points of contact on the condyles of the femur and the tibia are similarly

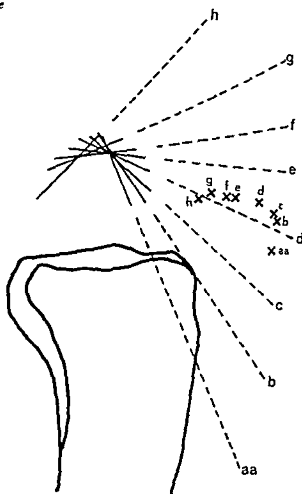


Figure 1 The movements of the I Bl (unbroken lines) and the apex patellae (crosses) during knee flection The extension of the I Bl (broken lines) The position aa corresponds to knee extension (in these subjects very close to the 180 degree position), the position b to 15 degrees, c to 30, d to 45 e to 60 f to 75, g to 90 and h to 110 degrees of flection

from 6 to 18 degree (with a mean of 10 degrees) The total dispersion of all measured values of *v* is from 29 degrees to 55 degrees The smallest values are always measured in the neutral position, and values increase with rotation, both inwards and outwards A medio lateral beam gives the same values as a latero medial one

By additional rotation of the X-ray film 30 degrees inwards or outwards, only a few more degrees are gained in addition to the mentioned highest or lowest values of *v*

DISCUSSION

The alteration of the direction of the I Bl during knee flection, as well as the relation to the wandering apex patellae, appears from Figure 1 The marked wandering of the apex patellae from zero to 30 degrees of

The movement backwards and downwards of the posterior point of the L Bl is caused by the continuous posterior diminishing of the radius of the evolvente This curved line (and a similar line described by the anterior point of the L Bl during knee flection) may be followed on Figure 1 Owing to the intermingled rolling and sliding movement of the femoral condyles on the tibia, and owing to the diminishing radius of the evolvente, a simple mathematical formula of the curved lines cannot be given But these complicated lines, as well as the movement of the whole L Bl and the movement of the apex patellae, stress the difficulties of the use of the L Bl as a "landmark" for the vertical location of the normal patella

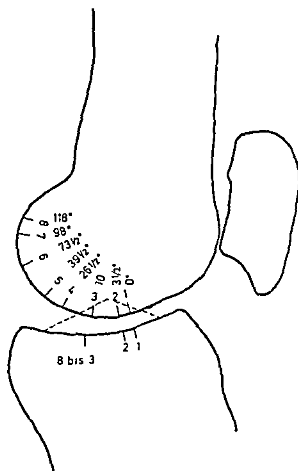
It is shown above that a considerable variation of the angle v is possible even in the same specimen, if the radiography is carried out on varied positions of the specimen in an X-ray beam of constant direction

In this connection it must be pointed out that the L Bl is defined as a line on the lateral radiograph of the knee joint, and that a line on the radiograph does not represent a definite line in the bone concerned Sharp lines on the radiograph of bones are found where the cortical bone is hit tangentially as stated by Lachmann (1937) and at the cartilage bone borderline in joints (Weiss 1943) The L Bl arises from the cortical bone in the roof of the femoral intercondylar fossa, where it is hit tangentially, which can be shown on a macerated bone (Lachmann and own experiments) However, the roof in the intercondylar fossa is curved in several directions and so different parts of it may be the cause of origin of the L Bl, if the position in relation to the X-ray beam is altered From this it follows that the location of the L Bl on the radiograph may be altered

The cause of the discrepancy between the mean values of the angle v, as given by Brattstrom and as given by us in our previous paper, is that his radiographs were not made under the same conditions of *projection* as ours The reason for his greater dispersion of the values of the *angle* v *is that his radiographs* were not made under strictly constant *circumstances Thus* we have been able to produce the same dispersion *(29 degrees to 55 degrees) as Brattstrom (27 to 60 degrees) by means* of rotation of the knee joints in a constantly directed X *ray beam*

This characteristic of the L Bl (that is varying location on the radiograph dependent on the position *of the knee in* relation to the direction of the X ray beam) also makes the use of the L Bl as a landmark for the vertical *location of* the patella unsatisfactory As mentioned in our previous *paper,* we propose the index of Insall & Salvati

Figure 2 Fischer's figure showing the corresponding points of contact on the condyles of the femur and tibia during knee flection



numbered The figures in degrees on the femoral condyle give the degree of knee flection, which corresponds to contact of each point with the tibia Note that the pure rolling movement takes place only in the beginning of flection, using the distance from point 1 to point 3 on the femur and point 1 to point "8 bis 3" on the tibia Figure 2 shows the medial condyles, in the lateral condyles, the rolling movement is continued a little longer In further flection the contact point will continue to be the same on the tibia, point "8 bis 3" The femoral condyle slides with its outline, evolvente (Fick), from point 3 to point 8, passing this same point on the tibia ("8 bis 3") Figure 2 can be reproduced on a template, with the femur made movable on the tibia, leaving an equal part of "cartilage" on each of them, the I BI can then be drawn on the femoral part (by means of a radiograph) Thus, the movement of the I BI can be constructed by the template being moved according to the corresponding figures on the two condylar parts The resulting Figure is identical to Figure 1

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(1971), LT/LP (length of patellar tendon/length of patella), be used instead

It should be pointed out that the mean value of the angle v (33 degrees) of the knee joint specimens in neutral position is the same as the mean value obtained from the 50 subjects in our previous work

Incorrectness of the location of the I Bl because of an oblique X-ray film (instead of a right angle position to the X-ray beam) is of little significance—and may be avoided by means of a raster in the plate holder

SUMMARY

An account of the movement of the line of Blumensaat during knee flection is given in the light of investigations of lateral radiographs of 5 normal subjects The results are correlated with the classic' mechanics of the joints" The simultaneous movement of the apex patellae is decribed as well Both movements contribute to the variation of the perpendicular distance from the apex patellae to the line of Blumensaat during knee flection

A material of 10 human knee joint specimens is investigated for the variation of the angle v, between the axes of the femoral shaft and the line of Blumensaat, dependent on the position of the joint in relation to the X-ray beam In this experiment a great dispersion of the values of v can be produced equal to the dispersion earlier found by Brattstrom This fact also contributes to the view that the line of Blumensaat is an unsatisfactory landmark for the normal vertical location of the patella We propose the index of Insall & Salvati be used instead

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Figure 1 Radiographic aspects (front and side view of the left knee after the reduction of the luxation)





Figure 2a Figure 2b

Figure 2 Radiographic aspects a) Bent knee without luxation b) Bent knee with luxation (positive Radulescu's sign)

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RECURRENT LUXATION OF THE SUPERIOR TIBIO-FIBULAR JOINT IN THE ADULT

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Recurrent luxation of the superior tibio-fibular joint has been detected very rarely and its existence is not mentioned in the classical speciality treatises or monographs on the knee Information is actually to be found in only two articles In the first, published by Dennis & Rutledge (1958), the authors report a case of posterior bilateral recurrent luxation, subsequently complicated by palsy of the external popliteal sciatic nerve, in a 27-year-old subject The second paper, published by Owen (1968), refers to two young girls, aged 15 and 16, with antero external recurrent tibio-fibular luxations

CASE REPORT

Our patient aged 45 was a miner and had practised his profession for 23 years Worthy of note in his past history was chronic polyarticular rheumatism Of late, without having suffered any trauma the patient began to complain of increasing pain on the external aspect of his left knee and at the same time a certain lack of stability his knee letting him down and sometimes even making a 'snapping sound The pains and the lack of stability appeared on walking and disappeared at rest In order to ease the pain he bent his knee slightly and used a walking stick for four months

The clinical and radiological examination revealed however an intact femoro tibio fibular joint (Figure 1) and no objective symptoms of lesion of the external meniscus were found On the other hand evidence was found of a particular symptomatology that of pains induced by deeper palpation of the anterior area of the head of the fibula and a positive Rădulescu sign Rădulescu & Baciu 1965) The Rădulescu sign resembles that described by Apley (1947) in lesions of the meniscus the patient in ventral decubitus the leg bent at the knee at an angle of 90°, with one hand the examiner fixes the thigh with the other he gets hold of the raised foot and rotates the leg inward Following this manoeuvre the head of the fibula is dislocated forward and outward (Figure 2) Antero external luxation of the head of the fibula may also be produced by the following manoeuvre used by us the patient lies in dorsal decubitus with the knee bent at an angle of 45°,



Figure 4 Radiographic aspects two years after surgery

a) the mechanism of production of the luxation
b) the particular aspect of the symptomatology, and
c) arguments in favour of the therapy adopted by us

The onset in our case was insidious without any trauma Our patient exhibited no signs of laxity of the capsulo-ligamentary system in the other joints, it being evident only at the level of the left superior tibio-fibular joint The cause of this isolated laxity remains obscure The inclination of the articular surfaces of the affected joint was normal It is most likely that the condition had an occupational character and was produced by the particular stress exercised upon the articulation during certain characteristic postures of a miner while working It is certain that luxation occurred spontaneously while walking, when the *weight was supported by the left leg, immediately after the vertical* moment and was likewise reduced spontaneously Luxation was always produced in the same position due to the interaction of the muscular contractions Before the vertical moment, the hamstrings and especially the crural biceps are under maximum tension in order to maintain extension of the knee that bears the whole weight of the body The fibular muscles are likewise under tension in order to second the



Figure 3 Radiographic aspects Front view of the left knee with luxation produced by forward and outward traction of the upper extremity of the fibula

the examiner lays his hand on the *leg below the knee* with the thumb on the anterior aspect of the *tibia and the four* fingers gripping the upper third of the fibula an attempt is made to draw this *forward* (Figure 3) Luxation can be easily produced by either of these two methods and is not painful when the patient *is lying in bed*

On walking normally (without holding the knee slightly bent to avoid pain) luxation occurred *spontaneously* and was painful as soon as the knee began to bend after the vertical moment and was reduced spontaneously on extending the knee

The patient was operated on in *October* (1970) when a superior tibio fibular *trans articular arthrodesis* was *performed* using a metallic screw Extra periostal resection of 1 5 cm of the fibula (where the upper third joins the middle third) was carried out Luxation of the head was likewise easily *produced intra operatively* the capsulo ligamentary apparatus being abnormally lax A plaster splint was applied post operatively for 10 days after which the patient was allowed to take his weight gradually on his foot and to walk

Examined two years after the operation the patient declared he no longer had any pains or lack of stability while walking he could now walk normally without a stick and extend his knee completely (Figure 4)

DISCUSSION

The case reported may be discussed from three points of view which we consider of interest

affords the crural biceps a solid point of insertion, and the pseudarthrosis focus permits the distal extremity of the fibula to move independently The therapeutic results obtained confirmed the use of our new surgical technique, which resembles Sauve-Kapandji's procedure for badly consolidated fractures of the lower extremity of the radius

Recognition and adequate treatment of recurrent *superior tibio-fibular* luxation represent an important element of differential diagnosis in the pathology of the knee It is likely that a certain proportion of arthrotomies in which no lesion of the external meniscus is found may be explained by the existence of an undetected recurrent superior tibio fibular luxation

SUMMARY

A rare case of left superior recurrent tibio fibular luxation which developed insidiously and without any trauma, in a 45-year-old miner, is reported The case was resolved by trans-articular arthrodesis with a metallic screw and extra periostal resection of the fibula at the level where the upper third joins the middle third The mechanism of production of this rare condition and its symptomatology, which may be confused with that of lesions of the external meniscus, are discussed

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activity of the anterior tibialis in flexion of the foot on the ground Being contracted the muscular chain maintains the upper extremity of the fibula in a normal position with respect to the upper extremity of the tibia Immediately after the vertical moment, under the influence of gravitational forces, the knee is slightly flexed by the weakening of the action of the hamstrings and remains under almost exclusive control of the quadriceps that contract isometrically On the other hand the contraction force of the fibular muscles increases The leg which bears the weight acts as a closed cinematic chain, the muscular group of the leg chose a distal fixed point of insertion, at the peripheral ends, towards the supporting base The fibular muscles act in the same way, drawing the fibula outward and forward and thus producing the luxation

The symptoms which the patient complained of resemble the symptomatology of lesions of the external meniscus This similitude with the subjective symptomatology may be misleading, although in lesions of the meniscus the anamnestic data are of the greatest importance The objective symptomatology is, however, sharply different, the manoeuvres for detecting lesions of the external meniscus being negative, except for Appley's sign, which corresponds with Rădulescu s sign, producing pain and the respective click, not due to clamping of the external meniscus but by producing superior tibio fibular luxation

Our therapeutic approach was conditioned by the patient s age Owen (1968) in his two cases, abstained from operating The only case of operated recurrent superior tibio fibular luxation we know of in the literature is that of Dennis & Rutledge (1958) A superior tibio fibular arthrodesis using a metallic screw was performed After three months the patient, who was 27 years old, came back with palsy of the fibular nerve He was reoperated and a few months later came back with deterioration of the arthrodesis and recurrence of the luxation After some time, broad bilateral resection of the superior extremities of the fibula was carried out In the first stage the arthrodesis applied was not sufficient, since operative blocking of the superior tibio-fibular joint also limits the function of the inferior tibio-fibular joint and therefore disturbs the dorsal and plantar flexion of the foot The resection of the upper extremity of the fibula practised in the second stage of treatment, appears to be closer to a better solution

The operative technique used by us consists in trans-articular arthrodesis with a metallic screw and the formation of a pseudarthrosis focus at the fibula The head of the fibula being fixed,

medial part of the first metatarsal head has been removed Thereafter, the great toe is dressed in slight, but not too marked overcorrection

At the Orthopaedic Hospital, Copenhagen, the McBride method was introduced in 1954, and since then it has been used, with minor modifications, in the treatment of a large number of patients To assess the results after a suitable observation period, a group of these patients have now been subjected to a follow up study

MATERIAL

During the period 1 4 1964 to 31 3 1967 a total of 107 patients were treated by the McBride operation at the Orthopaedic Hospital Copenhagen

Seven patients had to be left out of the material Three have died one foreigner cannot be traced 2 have gone abroad but have answered by letter that they are satisfied and have no complaints One patient cannot spare the time for a follow up examination and refuses to be X rayed but states that she is satisfied with the result

Another 9 patients were excluded for the following reasons One developed rheumatoid arthritis during the follow up period One has had an operation for the sequelae of traumatic contusion One had sequelae of poliomyelitis Two had foot deformities as a link in neurological diseases Two had previously undergone hemiepiphysiodesis because of metatarsus varus Simultaneously with the McBride operation one patient had had fusion of the cuneiform first metatarsal articulation During the period in question one patient had re operation after a previous McBride operation on the same foot three years later she had a McBride operation on the other foot too Now she has no complaints

This leaves 91 patients two of whom are men

In 25 cases the operation was carried out on the right foot in 18 on the left foot and in 48 cases it was bilateral Thus the study comprises 139 feet

Table 1 gives the age distribution at the time of the operation The youngest patient was 12 years of age and the oldest 67

Preoperative complaints 73 patients reported pain in the bunion 11 deformation

Table 1 Age distribution at the time of operation

Age at operation	Total no of patients	Group 1	Group 2	Group 3
10–19	18	12	3	3
20–29	12	7	3	2
30 39	14	9	3	2
40–49	21	12	5	4
50–59	21	10	7	4
60–69	5	2	2	1
Total	91	52	23	16

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HALLUX VALGUS TREATED BY THE McBRIDE OPERATION

A Follow-up

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McBride has described his method for the operative treatment of hallux valgus several times (McBride 1928, 1954, 1967) Its principle (Figure 1) is to alter the balance between the forces of the abductors and adductors of the great toe, at the same time the metatarsals are approximated and the position of the great toe is corrected

The adducting force upon the great toe is altered by transposing the insertion of the conjoined tendon from the transverse and the oblique heads of the adductor hallucis from the first phalanx of the great toe to the lateral aspect of the first metatarsal head The original description of the method (McBride 1928) also included transposition of the tendon from the lateral head of the flexor hallucis brevis, but later (1954) McBride altered the technique, warning against damaging the tendon, as this might give rise to a "cock-up toe"

In this method the conjoined adductor tendon is detached and the lateral sesamoid bone excised, since it contributes to increasing the deformity This facilitates the approximation of the metatarsals which is considered an important link in the operation McBride (1954, 1967) used either a fascial periosteal suture applied between the lateral aspect of the first metatarsal neck and the medial aspect of the second metatarsal neck or else a circumferential suture around the necks of both these metatarsals Joplin (1950) described a modification of the technique of approximating the metatarsals, carrying the conjoined adductor tendon through a drill hole in the first metatarsal and fixing it under tension He also used the extensor tendon from the fifth toe to reduce the spread of the metatarsals

The correction of the valgus deformity of the great toe is done by shortening the joint capsule on the medial aspect of the metatarso-phalangeal joint by a plication of the joint capsule after the prominent

Group 2 comprises 23 patients who are satisfied with the operation, but who nevertheless have some foot complaints All but one wear ordinary shoes, but have difficulties in finding shoes that fit

One is wearing hand made shoes because of hammer toes on the small toes

10 were unable to localize their complaints

1 had unchanged valgus deformity of the great toe

1 had complaints because of varus deformity

1 had pain at the bunion

6 complained of metatarsalgia, and 2 of them also had complaints because of a persisting bunion

Group 3 comprises 16 patients who are dissatisfied, but 6 of them only with one foot

2 have complaints because of persisting valgus deformity, but one of them merely for cosmetic reasons

2 have complaints because of varus deformity

3 have complaints because of flexion deformity

1 has combined varus and flexion deformity

2 have metatarsalgia as the main complaint

3 have osteoarthritis complaints from the metatarso phalangeal joint of the great toe as well as metatarsalgia and hammer toes in the small toes

3 have had re operation and will be described in more detail below

One had preoperatively a valgus deformity of 30° After the operation this changed to a 5° varus deformity which became accentuated in the course of 8 months to 15° Then a re operation was performed by the method of Keller Brandes At follow up the great toes still showed 5 and 10° varus deformity and flexion deformity The patient is wearing hand made shoes

The second patient who underwent a unilateral operation, had a preoperative valgus deformity of 40° After the operation varus and flexion deformity developed Eight months later interphalangeal fusion was performed The toe is still in varus, pointing dorsally The patient is wearing ordinary shoes with insoles

The third patient had preoperatively few complaints, with a valgus deformity of 25 30° After the operation both great toes were in varus

of shoes, 6 had only cosmetic complaints, and in one case the complaints are unknown

METHOD

The operation was carried out in a bloodless field Two incisions were applied one in the first interstice and one medially over the bunion The lateral sesamoid bone was removed in all but 10 patients The conjoined tendon from the transverse and oblique heads of the adductor hallucis was detached from its insertion on the first phalanx In 10 patients it was fixed to the lateral aspect of the first metatarsal head, in 18 patients it was anchored to a drill canal in the first metatarsal head and in 33 patients it was fixed medially, having been carried through a sub periosteal tunnel on the plantar aspect of the first metatarsal neck In 30 cases this information was not available The prominent part of the bone was removed in all the patients, and in all cases capsuloplasty was done on the medial aspect of the joint, correcting the great toe In cases where the adductor tendon was fixed medially or anchored in a drill canal the approximation of the metatarsals was done by means of this tendon, whereas it is not definitely known how the approximating sutures were applied in cases where the tendon was fixed laterally

Postoperative Treatment

In 36 cases the sutures were removed on the 14th postoperative day a walking cast was applied and worn for 3 weeks The remaining patients were allowed weightbearing immediately after the sutures had been removed i e on the 14th postoperative day in 48 cases and on the 21st postoperative day in 7 Most patients could be discharged after 3 or 4 days in hospital but for social reasons many were kept until the sutures had been removed

At the time of the McBride operation 15 patients had surgery for hammer toe on one or more of the small toes One patient had an operation for varicosities

Three patients developed superficial inflammation of the wounds which soon healed, but in one of them not until chronic catgut sutures had been rejected

RESULTS

All 91 patients were examined by the author and all were X-rayed The follow-up period ranged from 5 to 8 years, mean 6 years 4 months

In an endeavour to detect the reasons for the difference in operative results, the patients were divided into three groups on the basis of their subjective evaluation of the operation

Group 1 comprises 52 patients who have no foot complaints and all of whom wear ordinary factory made shoes One had cosmetic complaints on account of the varus deformity of the great toe

Group 2 comprises 23 patients who are satisfied with the operation, but who nevertheless have some foot complaints All but one wear ordinary shoes, but have difficulties in finding shoes that fit

One is wearing hand made shoes because of hammer toes on the small toes

10 were unable to localize their complaints

1 had unchanged valgus deformity of the great toe

4 had complaints because of varus deformity

1 had pain at the bunion

6 complained of metatarsalgia, and 2 of them also had complaints because of a persisting bunion

Group 3 comprises 16 patients who are dissatisfied, but 6 of them only with one foot

2 have complaints because of persisting valgus deformity, but one of them merely for cosmetic reasons

2 have complaints because of varus deformity

3 have complaints because of flexion deformity

1 has combined varus and flexion deformity

2 have metatarsalgia as the main complaint

3 have *osteoarthritis complaints from the metatarso* phalangeal joint of the great toe as well as metatarsalgia and hammer toes in the small toes

3 have had re operation and will be described in more detail below

One had preoperatively a valgus deformity of 30° After the operation this changed to a 5° varus deformity which became accentuated in the course of 8 months to 15° Then a re operation was performed by the method of Keller Brandes At follow up the great toes still showed 5 and 10° varus deformity and flexion deformity The patient is wearing hand made shoes

The second patient who underwent a unilateral operation, had a preoperative valgus deformity of 40° After the operation varus and flexion deformity developed Eight months later interphalangeal fusion was performed The toe is still *in* varus, pointing dorsally The patient is wearing ordinary shoes with insoles

The third patient had preoperatively few complaints, with a valgus deformity of 25 30° After the operation both great toes were in varus

Table 2 Valgus varus deformity of the great toe pre and postoperatively

	Group 1	Group 2	Group 3
Total no of feet	74	36	29
Angle preoperatively			
>45°	2	5	2
25–45°	59	24	20
10–25°	13	7	7
Angle postoperatively			
>45°	1	2	1
25–45°	16	8	6
10–25°	40	15	11
0–10°	15	5	1
Varus	2	6	10

position Nine months later a re operation was carried out by the Keller-Brandes method However, the varus deformity persisted, and 3½ years after the primary operation metatarso-phalangeal fusion was performed, but non-union remained on both sides This patient still has severe complaints, and she has been offered amputation of the left great toe She is wearing hand-made shoes

At the physical examination the position of the great toe was assessed, both without weightbearing and during walking, especially during push-off Active and passive mobility in the metatarso-phalangeal and interphalangeal joints of the great toe were measured Moreover, the patients were examined for hammer-toe formation in the small toes and for tender callosities under the forefeet

Table 2, giving the results for each foot, shows the distribution within the 3 groups of valgus and varus deformity of the great toe before and after the operation The measurement was done on the

Table 3 Postoperative occurrence of reduced ability for plantar flexion and flexion deformity given for number of feet within each group

	Group 1	Group 2	Group 3
Total no of feet	74	36	29
Reduced plantar flexion in proximal joint	10	13	14
Flexion deformity	1	10	7

basis of the X ray films, but compared with the clinical assessment It should be mentioned that in patients who exhibited varus deformity, this deformity was accentuated during weightbearing In the case of the 9 feet which had not been X rayed preoperatively, the evaluation was based on the clinical record of the valgus angle After the operation, a shift had occurred towards a lesser valgus deformity, in accordance with the aim A more outstanding factor, however, was the overcorrection that had taken place This was of increasing relative frequency in the direction of the group with the poorest results The 3 re operated patients are included in this analysis, as the re-operations were done because of varus deformity Moreover, there was in some cases a postoperative valgus deformity of less than 10° This gives an ungainly cosmetic result because of too great a distance between the first and second toe, although in most cases it has not caused functional complaints

Table 3 presents the patients' ability for active plantar flexion in the metatarso-phalangeal joint of the great toe Reduced function is taken to mean cases in which the great toe is 10° short of being flexed to the neutral position in the metatarso-phalangeal joint, i e so that the first phalanx is in *prolongation* of the axis through the first metatarsal bone Most people with normal feet are able to plantar flex the metatarso-phalangeal joint of the great toe 20 30° past the neutral position In the present material, however, a number of patients were incapable of active flexion beyond the neutral position in the non-operated foot, for which reason the above-mentioned limit was chosen

In the most severe cases the great toe could not even be brought passively to the neutral position In Table 3 this is recorded as *flexion deformity*, this permanent dorsal flexion position in the metatarso-phalangeal joint being accompanied by plantar flexion in the distal joint of the great toe This causes tenderness and possibly callosity on the dorsal aspect of the distal joint of the great toe due to the pressure from the shoes

One patient who had undergone re operation, stated that the great toe was gradually tending ever more inwards All the others felt that the great toe was in the same position at follow up as it had been immediately after the operation This applied to the correctly placed as well as to the overcorrected and undercorrected great toes

Tender plantar callosities beneath one or more of the 2nd–4th metatarsal heads had been recorded preoperatively in 51 feet and were present also at follow up In 16 feet they were demonstrated at follow-

Table 4 Radiological evidence of osteoarthritic changes in the proximal joint of the great toe pre and postoperatively, as a percentage of the total number of feet X-rayed within each group

	Group 1	Group 2	Group 3
Preoperatively	11	11	7
Postoperatively	24	39	25

up without having been recorded preoperatively In 17 feet they had been recorded preoperatively, but could not be found at follow-up

Hallux rigidus, i e deficient dorsal flexion in the metatarso-phalangeal joint of the great toe during weightbearing, had been recorded in 5 feet preoperatively, but was not found at follow-up This phenomenon was also not seen in other cases

X-ray Findings

At follow-up all the feet were X-rayed in the dorsal-plantar, lateral, and slightly oblique views

Nine feet had not been X-rayed preoperatively

The frequency of osteoarthritis pre- and postoperatively is presented in Table 4 The signs of osteoarthritis are taken to be a narrowed joint space with marginal sclerosis and possible osteophyte formation A single marginal exostosis is not interpreted as osteoarthritis All feet which had exhibited osteoarthritis preoperatively also showed such changes at follow-up The re-operated feet are not included in the postoperative analysis

The angles between the first and second and between the first and fifth metatarsal bones were measured in order to investigate in how many cases the metatarsals had been approximated during the opera-

Table 5 Radiological evidence of postoperative reduction of the angle between the first and second metatarsals as well as of the angle between the first and fifth metatarsals as a percentage of the total number of feet within each group

	Group 1	Group 2	Group 3
Angle between first and second metatarsal reduced	64	50	54
Angle between first and fifth metatarsal reduced	31	37	21

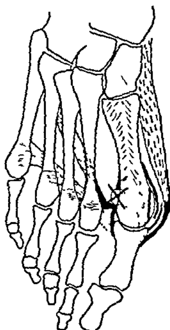


Figure 1 Principle of the McBride operation The insertion of the adductor hallucis tendon is transposed from the proximal phalanx of the great toe to the lateral aspect of the first metatarsal head The lateral sesamoid bone is excised The prominent medial part of the first metatarsal head is chiselled off The medial part of the joint capsule is shortened by a plication

tion The results are shown in Table 5 It should be mentioned that these angles may undergo marked variations due to a slight change in the projection Therefore, only those cases in which the angles had been reduced by 20 per cent were recorded

DISCUSSION

Summing up, the operative result may be classified as good (Figure 2) in 72 feet which make up 52 per cent of all operated feet These are the cases in which the patients have no complaints on account of great toes which are postoperatively in a valgus position of 0 25°

A fair result was found in 49 feet, corresponding to 35 per cent These patients had moderate complaints because of the great toes or else the operative result was not quite satisfactory because post-

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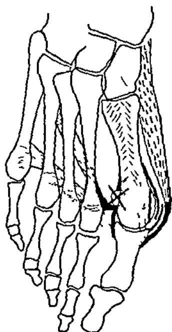


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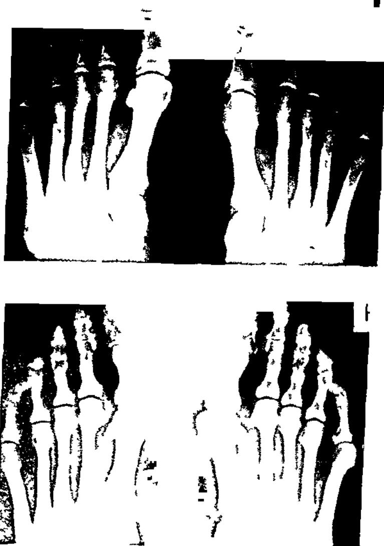


Figure 2. A good result after unilateral operation. A suitable valgus position and good approximation of the metatarsals.

operatively there was a valgus position of 25–45° or slight varus deformity.

Feet with severe varus or flexion deformity, or a combination thereof, and feet with persisting valgus deformity of 45° or over were designated as poor results. This applied to 18 feet or 13 per cent. The three re-operated patients are included in this group.

Analysis of the results (Table 1) showed that the age at operation



Figure 3 Overcorrection of the great toes and flexion deformity

was of the same relative distribution in all three groups The follow up period averaged 76 months in group 1 76 months in group 2 and 77 months in group 3

The times of removing the sutures the use of a plaster cast, and possible associated operation for hammer toe on the small toes showed a uniform distribution within all three groups

Minor radiological signs of osteoarthritis proved of no importance to

the operative result (Table 4). In 3 patients there were such severe degenerative changes in the feet pre- as well as postoperatively that this operative method should probably not have been used

From Table 2 it is apparent that the preoperative degree of the valgus deformity bore no relation to the operation result The less satisfactory results are seen to be related to the overcorrection and flexion position which had arisen This concerns primarily the operative procedure itself, as the position of the toe does not change after the operation

In the present material overcorrection was found in 11 patients, representing 18 great toes (Figure 3) Three patients had re-operation because of varus deformity, without a satisfactory result being obtained, as it proved extremely difficult to correct the toe again As pointed out by Hawkins (1971), the flexor hallucis longus, with the extensor hallucis longus, will maintain the varus deformity once the great toe has been carried medially to the axis through the first metatarsal bone and the effect of the adductor hallucis has been eliminated This presumably explains why it was impossible, in two cases, to correct the varus deformity by merely resecting the proximal part of the first phalanx of the great toe Hawkins (1971) has advocated a method by which the toe may be corrected by transposing the tendon from the abductor hallucis to the lateral aspect of the first phalanx of the great toe

The varus deformity, which has been just as much of a problem in other series (Jansen 1965, Ahlbeck 1967, Baciu & Scarbura 1969), is due to the fact that apart from removing the adducting factor represented by the adductor hallucis muscle, the operation may injure the lateral tendon from the flexor hallucis brevis during the dissection of the lateral sesamoid bone In that case the medial part of the flexor hallucis brevis will act as an abductor, if the toe is overcorrected, as a medial shift of the medial sesamoid bone may occur at the same time as the ligament between the medial and lateral sesamoid bone has been severed Hawkins (1971) therefore suggested omitting removal of the sesamoid bone In a number of the operative reports from the present material it is mentioned that in the course of the capsuloplasty medially an overcorrection has been attempted presumably in order to avoid a relapse This must be considered an error Hawkins (1971) also stated that too liberal a chiselling of the prominent part of the bone may contribute to overcorrection However, this occurred in some of the present cases without leading to varus deformity (Figure 4)



Figure 4 A good result without varus deformity although too much had been chiselled off the bone prominence

Accordingly, the alterations of muscle balance must be regarded as the main factor in overcorrection

Another complication is the flexion deformity which occurred in 18 feet This has been reported by others too (Jansen 1965, Ahlbeck 1967) In some patients the flexion deformity is *combined* with a varus deformity, giving the poorest possible result (Figure 3) The flexion deformity is caused by injury to the flexor brevis tendons *When the stabilizing factor is removed from the proximal* phalanx of the great toe, the extensor hallucis longus, the *extensor* digitorum

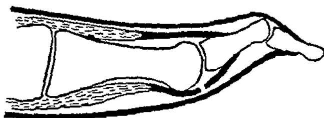


Figure 5 Flexion deformity of the great toe occurs due to the combined action of the extensor hallucis longus and brevis and the flexor hallucis longus, when the stabilizing effect of the flexor hallucis brevis has been eliminated

brevis, and the flexor hallucis longus will contribute to pulling the great toe into a flexion position (Figure 5) As already mentioned, the lateral part of the flexor hallucis brevis tendon may be damaged during the dissection of the sesamoid bone If the medial part of the flexor hallucis is damaged too, the flexion deformity will arise Possibly, no actual damage to the medial tendon is needed, since as already mentioned it may become displaced after removal of the sesamoid bone, thus losing its plantar flexing effect In the present material the conjoined adductor tendon had in several cases been carried beneath the plantar aspect of the first metatarsal neck, without any evidence that these patients, in particular, had sustained damage to the flexor brevis tendons On the other hand, varus or flexion deformities were not demonstrated among the 13 feet in which the sesamoid bone had not been removed

The clinical significance of approximating the metatarsal bones is in some doubt on the basis of the present material Radiologically it could be demonstrated that the metatarsals had been approximated in about half the cases (Table 5) The result of these goniometric studies was related to the finding of tender callosities under the forefoot, especially in patients whose callosities apparently disappeared after the operation, but it was not possible to demonstrate a relationship Moreover, the result of the radiological goniometry was related to the varying operative technique Although the values are too uncertain for actual assessment, it is striking that among the 16 feet in which the tendon was fixed laterally radiography showed approximation of the metatarsals in only one case Perhaps this indicates that the medial placement of the abductor tendon is the most effective method

On the basis of the present material it may be concluded that the McBride operation for hallux valgus has afforded many good results, but also a few poor ones which may be blamed on the operative

technique, as the toe remains in the position in which it has been placed at operation Overcorrection and injury to the flexor tendons must be avoided by using a careful technique, since otherwise the disability may become greater than that of the original problem The sesamoid bone should not be removed unless it is severely dislocated that it prevents approximation of the metatarsals However, the clinical significance of approximating the metatarsals has not been elucidated

SUMMARY

A follow up study was conducted on a series of 91 patients, representing 139 feet subjected to the McBride operation for hallux valgus Average follow up period was 6 years

The operative result was classified as good in 72 feet, or 52 per cent of all operated feet, as fair in 49 feet, or 35 per cent, and as poor in 18 feet, or 13 per cent

An analysis showed the poor results to be due primarily to a deficient operative technique, other factors—i e the patient's age, the severity of the preoperative valgus deformity, and minor radiological signs of osteoarthritis being of no significance

In the operation overcorrection should be avoided, and so should damage to the flexor hallucis brevis tendons It is advisable not to remove the lateral sesamoid bone except in a very few cases in which it is so dislocated as to prevent approximation of the metatarsals The clinical significance of approximating the metatarsals is in doubt

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PROCEEDINGS OF THE
DANISH ORTHOPAEDIC SOCIETY
91st ASSEMBLY

COPENHAGEN, DENMARK, SEPTEMBER 1973

THE ROLE OF THE ARTICULAR CARTILAGE IN THE AETIOLOGY OF OSTEOARTHRITIS

Rudolf Lemperg

Metabolic disturbances of the chondrocytes and alterations in the chemical properties of articular cartilage matrix are sometimes demonstrable in the early stages of degeneration Loss of keratan sulphate may occur before morphological alterations become visible and this is followed by loss of chondroitin sulphate Superficial articular cartilage defects induce an early reaction in the subchondral bone, consisting initially of loss of perivascular mineral and followed by accelerated formation of new bone In avascular articular cartilage of calves a factor is present which when injected into the cornea of rabbits consistently evoked ingrowth of vessels. It is suggested that in diseased articular cartilage a similar factor is produced or activated and is responsible for the vascular reaction in the subchondral bone

VASCULAR EXPERIMENTS RELATED TO OSTEOARTHRITIS

Murray Brookes

A vascular approach to osteoarthrosis encourages the development of useful diagnostic and prognostic measurements of intramedullary pressures, PO_2, PCO_2 and pH

Experimental femoral vein ligation suggests that osteoarthrotic bone sclerosis can be caused by a raised PCO_2 and PO_2 in the osseous circulation, together with a fall in pH Bone cysts occur when the pH is below 7 2 because of continuing bone removal with suspended bone formation

As for treatment, acrylic cement caused a sustained fall (25 per cent) in the blood flow rate and blood volume of the tibia, with 16 per cent incidence of sepsis against 2 per cent in controls After femoro-popliteal venous excision, vitallium screws provoked an increased flow rate in otherwise ischaemic bone Titanium and stainless steel were in this respect inert

McBride, E D (1967) The McBride bunion hallux valgus operation Refinements in the successive surgical steps of the operation *J Bone Jt Surg* 49 A 1675–1683

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Whether a post operative infection after total hip arthroplasties occurs early (without wound healing per primam) or late (with wound healing per primam) would seem to depend on which bacteria are contaminating the surgical site and whether this bacteria can establish an infection there. Staphylococcus aureus produces early infections whereas anaerobes and aerobic bacteria with a low virulence can have a long period of latency before symptoms appear No sterile culture should be accepted unless isolation of strictly anaerobic species has been performed

THE PRELIMINARY RESULTS OF 316 HIPS OPERATED WITH LOW FRICTION ARTHROPLASTY A M CHARNLEY

S Pilgaard

An account is given of the results of 316 hips operated a m Charnley The main indication for operation was osteoarthrosis (237 hips) 123 hips were operated on before the use of the "clean air operation room" In both periods the result concerning pain and joint movement was excellent Before the use of the sterile enclosure the rate of secondary infection with positive culture was 12 per cent (mean follow up—3 years) After the use of the sterile enclosure it was 1 per cent (mean follow up—1¼ year) 9 prostheses were removed in the first period, only one in the second

A special complication never described before, was noticed viz, fracture of the tip of the cement around the stem In a total of 20 hips the X ray showed, from 3 12 months after the operation a fine fracture line at a distance of a few mm to 2 cm from the tip of the metallic stem

TOTAL KNEE PROSTHESIS

M A R Freemann

A prosthesis and an operative procedure have been developed for the total replacement of the tibio femoral joint This procedure has now been in continuous clinical use at the London Hospital for three and a half years and in numerous other centres for shorter periods

The results in the first 69 patients with a follow up of not less than one year are presented With the procedure as it is now carried out pain on level walking has been eliminated in 91 per cent of patients valgus and varus instability or deformity of up to 30° have been corrected and flexion deformities of up to 100° have been eliminated The range of movement in knees having a pre operative range of 0–60° has on average been increased by 30° The maximum increase in the range of movement has been 75°

Two new versions of the prosthesis one to permit retention of the cruciate ligaments and one to permit replacement of the patello femoral joint in addition to the tibio femoral joint are described.

LONG TERM EFFECT OF INTERTROCHANTERIC OSTEOTOMY ON THE INTRAOSSEOUS PRESSURE OF THE FEMORAL HEAD AND GREATER TROCHANTER IN PATIENTS WITH OSTEOARTHRITIS OF THE HIP JOINT

N B Termansen & K Olholm

In 16 patients with osteoarthritis of the hip joint, intraosseous pressure was measured before and a year after intertrochanteric osteotomy The mean pressure of the femoral head was higher than that of the greater trochanter After healing of the osteotomy the mean pressure of the femoral head was reduced significantly A fall in pressure was shown in the greater trochanter, but it was not significant The clinical effect of the operation was good, and none of the patients suffered from pain at rest at the re examination Disappearance of pain at rest may be explained by a long lasting reduction of intraosseous hypertension

LATE INFECTIONS AFTER TOTAL HIP ARTHROPLASTY

Lars Lidgren

Today total hip arthroplasty according to the Charnley method presents few technical complications The most serious problem remaining concerns the deep infections which appear with a frequency of 1 to 12 per cent in several series Such infections often necessitate the removal of the prosthesis with permanent invalidism as the result

In two separate hospitals Malmo and Lund it was shown in a double blind study of 171 hip operations that prophylactic treatment with cloxacillin significantly reduced the frequency of early post operative infections The first group receiving prophylactic cloxacillin had no post operative infection while the second placebo group had 12 (out of 88 patients) All of the patients had major surgery to the hip and 10 of the 12 infections were caused by staphylococcus aureus We also observed a significant reduction in the same material of late reactions following total hip arthroplasties according to Charnley

The radiographic signs of infection in 14 patients with Charnley total hip arthroplasties were compared with a non infected control group It was found that half of the non infected hips developed a radiolucent zone around the femoral component However this zone never increased in width beyond 6 months post operatively and was always less than 2 mm in width In comparison with the control hips 6 of the infected hips developed a z ne wider than 2 mm as early as 12 weeks post operatively and 2 of these had scalloping of the cortical bone By 52 weeks all infected hips had clear radiographic signs of infection Radiographic prediction of looseness of the components was found to be correct at re operation for all femoral components but false for 3 acetabular sockets in 7 re operated cases

At re operation of 7 patients with late infection following total hip arthroplasty according to Charnley obligate anaerobic bacteria were isolated from 4 of the patients Staph epidermidis (albus) was isolated in one additional patient Two of the patients from whom no bacteria were isolated were on antibiotic therapy at the time of re operation In 3 of the 4 patients from whom anaerobic bacteria were isolated a significant decrease in the titre of agglutinating antibodies against the patient s own strain was observed 6 months after re operation and antibiotic treatment

UNSTABLE PERTROCHANTERIC FRACTURES OF THE HIP

M Michaelsen & J S Jensen

Out of 317 patients with pertrochanteric femoral fractures 305 were treated with McLaughlin osteosynthesis The primary mortality rate was 14 5 per cent The post-operative complication frequency (35 8 per cent) was dominated by cardio-pulmonary (12 5 per cent) and thromboembolic (12 6 per cent) diseases Wound infection was found in 3 7 per cent and ostitis in 0 9 per cent

106 patients had stable fractures Among these, four had to be reoperated due to penetration or a loose bolt

211 patients (66 5 per cent) had unstable fractures according to Evans' classification At the follow up of 166 patients, ⅔ were found to be healed in an unchanged position Only 14.8 per cent of the 166 patients had significant fracture complications mostly varus angulation of more than 20° (9 patients) or penetration of the nail (8 patients) 10 patients (5 9 per cent) had to be reoperated because of varus angulation penetration, broken plate or pseudarthrosis after removal of the osteosynthesis material

McLAUGHLIN FAILURE

P Østergaard

In Frederiksberg Hospital Surgical Department A, we have investigated 222 patients who were operated a.m McLaughlin for pertrochanter and subtrochanter fractures of the femur In 4 of these 222 patients (2 per cent) the top screw had worked loose

Our opinion is that too high a temperature and repeated sterilization can damage the nylon bush of the top screw If the top screw is screwed in it must be loosened and then screwed in again

The nail supports on the edge of the bow by the splint

We think that a material with a fixed connection between nail and splint could prevent these 2 per cent failures

MOORE ARTHROPLASTY IN FRACTURED FEMORAL NECK. A SURVEY

J S Jensen & P Holstein

In 169 Moore hip arthroplasties 48 9 per cent of postoperative complications were dominated by cardiopulmonary and thromboembolic diseases

The three month mortality rate was 21 6 per cent but there were 140 serious preoperative complications in 107 patients The life-table showed good prognosis on survival after the first year, but 30 5 per cent had to be placed in nursing homes most often for other reasons

Follow up of 52 patients (observation period 2 5–10 years, mean 4 7 years) showed significantly reduced mobility in the case of osteolysis and sinking more than 20 mm while osteosclerosis in the fenestres resulted in significantly better movement and less pain.

15 hips were classified as excellent 13 as good, 21 as fair and 3 as poor In 69 4 per cent the hips were painless, 76.8 per cent had satisfactory hip mobility and 40 4 per cent could walk more than 500 meters

COPENHAGEN, DENMARK, MAY 1974

RESULTS AFTER FRACTURE OF THE NECK OF THE FEMUR IN CHILDREN

H Kristensen & K Olholm

A follow up of 25 fractures of the neck of the femur in children below 15 years of age has been carried out Complications such as no primary healing avascular necrosis or healing in a varus position in a third of the cases

Thirteen patients had no symptoms and X ray showed normal conditions Four answered by letter that they were symptom free. Five patients had pain limitation of movement and/or pathological X rays Mean observation period 13 7 years

We cannot conclude that any special method of treatment is to be preferred but other authors have recommended osteosynthesis with screws

TREATMENT OF FRACTURES OF THE FEMORAL NECK IN CHILDREN

Soren Pilgaard

The earliest report of fracture of the femoral neck in children appears to have been made in 1885 by Cromwell Næraae in 1938 found that fractures of the neck of the femur in children were so unusual and rare that it was reasonable to call attention to them As Kristensen & Olholm (1974) point out the condition is uncommon but not rare Ratcliff (1970) found out of 132 cases of these fractures in children 61 per cent with complications

In the last 6 months we have had 4 cases of fractures involving the neck of the femur transferred to the Orthopaedic Hospital in Aarhus The complications have been necrosis of the proximal fragment delayed union and varus position

We recommend the subtrochanteric osteotomy as used by Thomasen The purpose of the treatment is to transform a vertical fracture line to a horizontal fracture line The changing of the power lines introduces healing in a few weeks

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TREATMENT OF FEMORAL NECK FRACTURES BY FOUR COMPRESSING AO CANCELLOUS SCREWS

H Paaby

A preliminary statement regarding 27 cases of medial collum femoris fracture treated with 4–5 compressing AO cancellous screws with a short thread The method is simple and non traumatic and is expected to reduce the frequency of avascular necrosis of the femoral head

POSTTRAUMATIC FERROKINETICS

D Zdravkovic

We found a constant and marked decrease in serum iron after trauma on a selected group of orthopaedic patients, at the Orthopaedic Department, Odense University Hospital

To investigate the problem dogs were used as experimental animals They were found to be a good experimental model for ferrokinetic investigations (iron 59) because their iron metabolism is similar to man's Iron distribution was followed after injection of isotope for a 14-day period with plasma, red blood cells and organ activity measurements

From our results it can be concluded that the reticulo endothelial system plays a very important role in posttraumatic iron metabolism The reticulo-endothelial system has an increased affinity for iron and the iron becomes firmly bound intracellularly for about a 10–14 day period This means that a new distribution of iron in the organism after trauma is tending towards an iron deficient state where bone marrow has to work under a markedly decreased quantity of available iron

CONGENITAL CLUBFOOT

K Jorring & L Christiansen

A series of 58 children with 75 idiopathic congenital clubfeet is presented Early soft tissue release was performed in 77 per cent The results were poor in 12 feet, 11 (19 per cent) were reoperated upon On reevaluation of the poor cases we found severe social problems involved including neglectful parents

SURGICAL TREATMENT OF 100 ACHILLES TENDON RUPTURES

P Jessing & E Hansen

102 subcutaneous achilles tendon ruptures were treated by operation over a period of 28 years 54 with simple suture 48 with tenondoplastic a m Silfverskjold The two methods are compared with each other and with recent information about satisfactory results of non-operative treatment Operative treatment must still be advised Complications were few not affecting time of treatment or final results There was no mortality The functional results showed no statistically significant differences yet there was a tendency for more complaints following plastic procedures

Taking up full sporting activities after achilles tendon rupture can lead to rupture of the opposite tendon in up to approx 25 per cent of cases

GONYLAXOMETRY A RADIOLOGIC METHOD FOR MEASUREMENT OF MEDIAL, LATERAL AND DRAWER LOOSENESS IN THE KNEE JOINT

K Jacobsen

An account is given of an apparatus the gonylaxometer for measurement of medial lateral and drawer looseness by means of a hydraulic action of the knee joint by well-defined forces The measurements are based on radiographs. The

FOLLOW UP OF RESULTS FROM 11 ORTHOPAEDIC SURGICAL DEPARTMENTS OF ABOUT 400 CASES OF HIP ARTHROSIS, TREATED WITH RING's TOTAL PLASTY

H Paaby

Presentation is made of a material of 400 complete replacement arthroplasties of the hip, operated a m Ring, from 11 orthopaedic departments during the period 1968–1974

The pre- and postoperative condition has been estimated using the scale of Merle d'Aubigne

There were improvements as regards pain (1 3 to 5 1 points), mobility (2 5 to 4 6 points) and walking capacity (2 2 to 3 9 points)

Two patients died as a consequence of the operation, one died 12 days after the operation from apoplexia cerebri Deep, late infection was seen in 3 cases (0 7 per cent) and led to the removal of the prosthesis Two of these cases went over subsequently, *without complications, to a Girdlestone hip In 6 hips the prosthesis* was removed because of loosening The patient's own estimation was excellent 61 per cent, good 34 per cent, unchanged 4 per cent, aggravated 1 per cent

THE MONK TOTAL HIP PROSTHESIS

K Rechnagel

The recently developed Monk total hip prosthesis is now in use in the Orthopaedic Department in Hillerød Denmark

The first 17 cases confirm that the *primary* results are comparable to the results in other more complicated total hips In patients suffering from subcapital fractures or avascular necrosis of the femoral head the recovery and rehabilitation periods are greatly reduced as compared with Moore's prosthesis

The operative technique is so simple that bilateral operation is possible and even old patients in a poor medical condition may be operated

It seems to be a real improvement as compared to Moore s prosthesis and so far it is a valuable supplement to the many total hip constructions in the treatment of osteoarthrosis of the hip

SCINTIGRAPHY IN FEMORAL HEAD NECROSIS FOLLOWING RENAL TRANSPLANTATION A PRELIMINARY REPORT SUGGESTING A SURGICALLY INDUCED VASCULAR TRIGGER FACTOR

C J Edeling J Heerfordt & K Olgaard

Necrosis of the femoral head following renal transplantation occurs in about 10–20 per cent of cases at Rigshospitalet in 18 hips of 15 patients (8 per cent) In 11 out of 12 patients a unilateral necrosis was located ipsilateral to the graft In transplantation the hypogastric artery is sacrificed It is suggested that the seizure of the hypogastric supply to the femoral head is the trigger in the development of ipsilateral necrosis Until now we have made 84 posttransplant scintigraphies preceded by a pilot examination of 13 patients with hip pain 5 of these 13 had necrosis as seen radiologically versus 10 by the more sensitive method of scintigraphy

Acta orthop scand 45, 801-808, 1974

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LONG-TERM EFFECTS OF HIGH PHOSPHATE INTAKE ON PARATHYROID HORMONE LEVELS AND BONE METABOLISM

JENIFER JOWSEY, ERIC REISS & JANET M CANTERBURY

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Evidence has been accumulating over a number of years that phosphate supplements, and possibly dietary phosphate intake, may cause accelerated bone loss In early studies (Krook & Lowe 1964, Joyce et al. 1971, Draper et al 1972), predominantly in young animals, high dietary phosphate levels produced frank secondary hyperparathyroidism accompanied by hyperphosphatemia, however, in later studies (Jowsey & Balasubramaniam 1972, Laflamme & Jowsey 1972) in adult animals, a disease resembling osteoporosis was produced and was characterized by increasing bone porosity and normal serum chemistry values The suggestion has been made that osteoporosis may be a form of low grade secondary hyperparathyroidism, and in some patients the osteoporosis was found to be associated with serum parathyroid hormone (PTH) levels above normal (Fujita et al 1973, Riggs et al 1973)

In a previous study (Laflamme & Jowsey 1972), increased PTH levels and decreased bone mass resulted from oral phosphate supplements However, the exact sequence of events leading to stimulation of the parathyroid glands was not studied

The present investigation was designed to find the cause of the bone changes by measuring the effect of a high-phosphate diet on PTH secretion and on bone

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advantage of the radiologic method over "external" measurements is the elimination of inaccuracies caused by displacements in the soft tissues.

The accuracy of the method was evaluated by a test-retest examination of 50 healthy subjects. The radiographs were coded and measured at random after cessation of examinations in the gonylaxometer. The accuracy is ± 1 mm (SD 0.55) for medial/lateral looseness, ± 2 mm for drawer looseness.

A FOLLOW-UP STUDY OF 23 PATIENTS AFTER OPERATIO PLASTICA LIGAMENTI CRUCIATI ANTERIORIS GENUS A. M. JONES, BASED ON CLINICAL EVALUATION AND GONYLAXOMETRY

K. Jacobsen & P. Rosenklilde

During the period from 1.3.1971–1.9.1973, 27 operations have been carried out on patients with knee instability caused by the lack (non-acute) of the anterior cruciate ligament. The method described by Kennet G. Jones (1963) was used.

23 patients have been followed up until now. At the clinical examination we found considerable improvement in the stability of the knee joints. In the patients' opinion 70 per cent of the results were very good, 20 per cent better. Estimated by gonylaxometry, a radiographic measuring method, 50 per cent were normal and a further 30 per cent good.

FRACTURE OF THE TALUS

O. Sneppen & O. Buhl

In a material of 2456 ankle fractures there were 25 cases of associated ankle fracture and talar fracture or subtalar dislocation. On the basis of a genetic classification of the ankle fracture, it could be concluded that the position of the foot at the moment of the accident was of decisive importance in the frequency of occurrence of talar fractures, supination in particular predisposing to fracture of the neck as well as the trochlea of the talus.

Table 2 Serum calcium phosphorus and iPTH values and body weight

Period	P supplement (g/day)	Serum Ca (mg/dl)	Serum P (mg/dl)	Serum iPTH (µl eq/ml)	Body weight (kg)
1 Normal	0	10 8±0 2	4 6±0 6	–	13 7±2 5
2 Control	0	10 6±0 3	4 6±0 5	55 3±14 1	13 6±2 5
3 Phosphate	2 40	10 5±0 3	3 7±0 5*	–	13 6±1 9
4 Phosphate	2 73	10 3±0 2	3 8±0 9	–	13 4±1 8
5 Phosphate	3 06	10 1±0 3†	4 2±1 2	–	12 7±1 8*
6 Phosphate	3 36	10 4±0 2	3 1±1 2	–	12 7±1 8*
7 Phosphate	3 36	9 7±0.3†	3 9±0 6	142 5±53 2†	13 0±1 8

For difference from control $P < 0\ 05$

† For difference from control $P < 0\ 005$

Student s *t* test was used to compare all data In all tables the values are the mean and one standard deviation of the mean

RESULTS

The fasting serum calcium values tended to decrease and were significantly below the control values during the fifth and seventh (phosphate supplement) periods (Table 2) The fasting serum phosphorus levels also tended to decrease but were significantly lower only during period 3 Serum iPTH increased approximately threefold between the beginning and end of the experiment The balance studies showed a significant increase in urinary phosphorus and a slight increase in urinary calcium (urinary calcium levels in adult dogs are normally very low compared with man) but no change in fecal calcium or phosphorus from the control period to the end of the experiment (Table 3)

Table 3 Fecal and urinary calcium and phosphorus values during balance studies

	Control (period 2)	PO_4 supplement for 2¾ months	PO_4 supplement for 5 months
Urinary Ca (mg/24 h)	3 48±0 65	6 64±3 65	4 46±1 96
Urinary P (mg 24 h)	262 2±32 7	2 197 4±170 7*	2,398 8±409 6*
Fecal Ca (g 24 h)	1 10±0 10	1 20±0 19	0 92±0 086†
Fecal P (g 24 h)	0 63±0.22	0 97±0 22	0.85±0.16

For difference from first balance study $P < 0\ 0005$

† For difference between second and third balance studies $P < 0\ 05$

Table 1 Dietary regimen for control and experimental periods

Period	Ca P ratio of diet	Content of diet (g/day)		Time (weeks)
		Ca	P	
1 Normal	1 0 7	3 9	2 8	28
2 Control	1 0 9	1 1	1 1	35
3 Phosphate supplemented	1 2 2	1 1	2 4	39
4 Phosphate supplemented	1 2 5	1 1	2 7	44
5 Phosphate supplemented	1 2 8	1 1	3 1	48
6 Phosphate supplemented	1 3 1	1 1	3 4	53
7 Phosphate supplemented	1 3 1	1 1	3 4	57

MATERIAL AND METHODS

Six adult female dogs with roentgenographic evidence of closure of the epiphyse were maintained on dog chow (calcium phosphorus ratio, 1 0 7) for 28 weeks At the beginning of the last month on this diet fasting state blood was drawn for serum calcium and phosphorus measurements The dogs were then given a control diet consisting of Red Heart meat Wayne dog meal and bread (calcium phosphorus ratio 1 0 9) for 7 weeks This diet fed twice a day at 0830 and 1600 hours decreased the daily calcium and phosphorus intakes but did not significantly alter the ratio of these two elements in the diet (Table 1) After the dogs had been on this diet for 4 weeks they were placed in metabolic cages for 5 days and urine and feces were collected Fasting state blood was drawn for serum calcium and phosphorus determinations every month

Two weeks later while the same diet was being fed blood was drawn for a feed sequence The samples were obtained in the fasting state and ¼ 1 2 4 6 and 7½ hours after the morning meal and serum was analyzed for both total and ionized calcium phosphorus immunoreactive PTH (iPTH) total protein and pH The dogs then were given oral phosphate supplements in the form of Hyper Phos K* in increasing amounts for 5 months At the final level of phosphate supplementation the calcium phosphorus ratio was 1 3 1 Fasting state blood was drawn for serum calcium and phosphorus determinations at the end of each month on the phosphate supplemented diets on the day before the supplement was increased At the end of 2½ and 5 months on the supplemented diets the 5 day balance studies were repeated On the last day of the experiment the feed sequence was repeated and a bone biopsy specimen was taken from the right ulna Control ulna samples taken from 15 adult dogs were used for comparison The porosity of the bone was evaluated by counting the number of holes in the cortex on a photographic enlargement (× 42) of the microradiograph large holes were divided into 2 mm square spaces the approximate size of the smallest hole of significant size

* The Hyper Phos K a gift from Davies Rose Hoyt Pharmaceutical Division of the Kendall Company, was in tablet form the tablets were ground and added to the diet

Table 5 Immediate preprandial and postprandial serum calcium and phosphorus values

Time	Serum Ca (mg/dl)	Serum P (mg/dl)
	Control period	
0 hour	10.6±0.3	4.6±0.5
½ hour	10.6±0.4	3.4±0.6*
1 hour	10.5±0.3	3.7±0.8*
1½ hours	10.5±0.2	3.8±0.9
	Phosphate supplement (period 7)	
0 hour	10.4±0.4	3.4±0.5
½ hour	10.5±0.4	3.1±0.4
1 hour	10.5±0.4	4.0±0.5
1½ hours	10.5±0.3	4.9±0.6*

For difference from T=0 value * $P < 0.05$ ** $P < 0.001$

creased significantly at 4 and 6 hours after feeding *In this period, as* a whole the ionized calcium values were significantly ($P < 0.001$) lower postprandially (mean ± SD 4.0 ± 0.1 mg/dl) than preprandially (4.50 ± 0.43 mg/dl) *The change in ionized calcium was not associated* with any significant alteration in the blood pH, although the phosphate supplements tended to produce an increase in pH The serum iPTH values all were increased compared with *control values and, in addi*tion the values at 4 hours after feeding were increased significantly above the preprandial values A significant negative correlation was found *between the serum ionized calcium and serum phosphorus* values ($r = -0.58$ $P < 0.005$)

The porosity of the ulna cortical bone samples showed a significant increase when compared with samples from adult control dogs fed the normal diet (mean ± SD normal 14.3 ± 6.4 phosphate supplement, 34.5 ± 26.6 $P < 0.001$)

DISCUSSION

The calcium phosphorus ratio in the diet of the average western man is at least 1 2 (0.8 g of calcium to 1.6 g of phosphorus) The normal and control diets in this study therefore represent an unusual calcium-phosphorus ratio The higher calcium content may explain the slight *increase in ionized* calcium that occurred postprandially, this is dif-

Table 4 Serum calcium (total and ionized), phosphorus, iPTH, and protein dur feed sequences

Time	Serum Ca (mg/dl) Total	Ionized	Serum P (mg/dl)	Serum iPTH (μl eq/ml)	S P (g
			Control period		
0 hour	10.6±0.3	4.36±0.41	4.6±0.5	55.3±14.1	6.10±
2 hours	10.6±0.2	4.48±0.63	4.1±1.0	74.7±24.7	6.10±
4 hours	10.3±0.3***	4.65±0.05	4.7±1.0	66.7±20.2	6.00±
6 hours	10.2±0.3****	4.58±0.32†	5.6±1.3†	54.8±11.3	5.80±
7½ hours	10.1±0.2****	–	5.7±1.0†	–	–
			Phosphate supplement (period 7)		
0 hour	10.4±0.4	4.11±0.06	3.4±0.5*	142.5±53.2*	5.8
2 hours	10.5±0.4	4.05±0.75	5.5±0.9*†	159.5±58.4*	5.95–
4 hours	10.1±0.1	3.97±0.12****†	7.7±1.1**†††	186.3±70.4*†	5.8
6 hours	10.1±0.2	3.98±0.09*	9.3±1.5**†††	149.8±76.0*	5.92±
7½ hours	10.1±0.3***	–	9.3±1.7**†††	–	–

* For difference from control value
*, $P < 0.05$,
**, $P < 0.01$,
***, $P < 0.005$,
****, $P < 0.001$
† For difference from T=0 value
†, $P < 0.05$,
††, $P < 0.01$
†††, $P < 0.001$

The feed sequence during the control period, on a calcium-phosphorus ratio of 1 0.9, showed a tendency for the total serum calcium to decrease although the ionized calcium value was increased at 6 hours (Tables 4 and 5) Serum phosphorus decreased initially and then increased at 6 and 7½ hours after feeding There was no significant change in the serum iPTH levels After 22 weeks of phosphate supplementation, the feed sequence showed a similar serum calcium decrease after feeding and a similar initial decrease in serum phosphorus which, however, was not statistically significant This was followed by an increase that was more rapid and more marked compared with the control period There was a significant change in the serum calcium values although the serum phosphorus levels were lower preprandially and then higher postprandially during the phosphate supplement period The serum ionized calcium de-

Table 5 Immediate preprandial and postprandial serum calcium and phosphorus values

Time	Serum Ca (mg/dl)	Serum P (mg/dl)
	Control period	
0 hour	10 6±0 3	4 6±0 5
½ hour	10 6±0 4	3 4±0 6**
1 hour	10 5±0.3	3 7±0 8*
1½ hours	10 5±0 2	3 8±0 9
	Phosphate supplement (period 7)	
0 hour	10 4±0 4	3 4±0 5
½ hour	10 5±0 4	3 1±0 4
1 hour	10 5±0 4	4 0±0 5
1½ hours	10 5±0.3	4 9±0 6*

For difference from T=0 value * $P < 0\ 05$ ** $P < 0\ 001$

creased significantly at 4 and 6 hours after feeding In this period, as a whole the ionized calcium values were significantly ($P < 0\ 001$) lower postprandially (mean ± SD 4 0 ± 0 1 mg/dl) than preprandially (4 50 ± 0 43 mg/dl) The change in ionized calcium was not associated with any significant alteration in the blood pH although the phosphate supplements tended to produce an increase in pH The serum iPTH *values all were increased compared with control values and, in addi*tion the values at 4 hours after feeding were increased significantly above the preprandial values A significant negative correlation was found between the serum ionized calcium and serum phosphorus values ($r =$ 0 58 $P < 0\ 005$)

The porosity of the ulna cortical bone samples showed a significant increase when compared with samples from adult control dogs fed the normal diet (*mean ± SD normal 14 3 ± 6 4 phosphate supplement,* 59 5 ± 26 6 $P < 0\ 001$)

DISCUSSION

The calcium phosphorus *ratio in the diet of the average western man* is at least 1 2 (0.8 g of calcium to 1 6 g of phosphorus) The normal and control diets in this study therefore represent an unusual calcium-phosphorus ratio The higher calcium content *may explain the slight* increase in ionized calcium that occurred postprandially, this is dif-

Table 4. Serum calcium (total and ionized), phosphorus, iPTH, and protein durin feed sequences

Time	Serum Ca (mg/dl) Total	Ionized	Serum P (mg/dl)	Serum iPTH (μl eq/ml)	Serum p (g/c
			Control period		
0 hour	10 6±0 3	4 36±0 41	4 6±0 5	55 3±14 1	6 10±0
2 hours	10 6±0 2	4 48±0 63	4 1±1 0	74 7±24 7	6 10
4 hours	10 3±0 3***	4 65±0 05	4 7±1 0	66 7±20 2	6 00±0
6 hours	10 2±0 3****	4 58±0 32†	5 6±1 3†	54 8±11 3	5 80±0
7½ hours	10 1±0 2****	–	5 7±1 0†	–	–
			Phosphate supplement (period 7)		
0 hour	10 4±0 4	4 11±0 06	3 4±0 5*	142 5±53 2*	5 82±0
2 hours	10 5±0 4	4 05±0 75	5 5±0 9*†	159 5±58 4*	5 95±0
4 hours	10 1±0 1	3 97±0 12****†	7 7±1 1**†††	186 3±70 4*†	5 80±0
6 hours	10 1±0 2	3 98±0 09*	9 3±1 5**†††	149 8±76 0*	5 92±0
7½ hours	10 1±0 3***	–	9 3±1 7**†††	–	–

* I or difference from control value
*, $P < 0\ 05$,
**, $P < 0\ 01$,
***, $P < 0\ 005$,
****, $P < 0\ 001$

† I or difference from T=0 value
†, $P < 0\ 05$,
††, $P < 0\ 01$,
†††, $P < 0\ 001$

The feed sequence during the control period, on a calcium-phosphorus ratio of 1 0 9, showed a tendency for the total serum calcium to decrease although the ionized calcium value was increased at 6 hours (Tables 4 and 5) Serum phosphorus decreased initially and then increased at 6 and 7½ hours after feeding There was no significant change in the serum iPTH levels After 22 weeks of phosphate supplementation, the feed sequence showed a similar serum calcium decrease after feeding and a similar initial decrease in serum phosphorus which, however, was not statistically significant This was followed by an increase that was more rapid and more marked compared with the control period There was a significant change in the serum calcium values although the serum phosphorus levels were lower preprandially and then higher postprandially during the phosphate supplement period The serum ionized calcium de-

intake, had a slower bone loss than the omnivorous group (Mazess 1970, Ellis & Ellis 1972) Although iPTH levels were not measured in these studies, a relationship among high phosphorus intake, stimulation of PTH secretion, and accelerated bone loss is a probable cause of their disease

Some years ago, Wachman & Bernstein (1968) suggested that the acid content of the diet may play a significant role in bone loss in older persons Because meat has a high "acid ash", the bone loss in the human studies cited could be the result of both the acid and the high phosphate content of the diet However, in the present animal study, the additional phosphate was administered as a neutral mixture and there was no significant change in blood pH, either postprandially or in the fasting state, suggesting that phosphate supplements alone will cause bone loss

Osteoporosis is a common disease The present studies incriminate the high phosphate intake by the average person as contributory toward the disorder and possibly as a major etiologic factor in the development of bone loss

SUMMARY

Phosphate supplementation or dietary phosphate content may be an important factor in the etiology of bone loss that occurs with increasing age Previous studies have suggested that large discrepancies in the phosphorus to-calcium ratio in favor of phosphorus will produce biochemical and pathologic changes characteristic of secondary hyperparathyroidism Smaller differences produce a state indistinguishable from osteoporosis The present study in adult female dogs was designed to investigate the effects of a phosphorus to-calcium ratio higher than 1 on parathyroid hormone (PTH) secretion and bone morphology After long term administration of phosphate, PTH levels were found to be minimally but significantly increased and bone loss was increased Urinary calcium was not changed, while serum calcium tended to decrease Postprandial measurements after phosphate administration demonstrated a transient decrease in ionized calcium, which was associated with transient hyperphosphatemia and an increase in serum PTH Long term administration of phosphate produced a sustained increase in serum PTH The studies suggest that the bone loss is mediated by small increases in PTH that result from a phosphate induced decrease in ionized calcium

ficult to explain otherwise in view of the decrease in total calcium, increase in phosphorus, and no significant alteration in serum protein. The immediate decrease in serum phosphorus after phosphate loading is probably an expression of PTH action on the renal excretion of phosphorus because this was found in the fasting animal as well as after feeding; this was related to an increase in hormone levels and also was reflected in the increase in porosity of bone. Presumably, the stimulation of PTH production was mediated by the significant decrease in ionized calcium 4 hours postprandially; ionized calcium also tended to be lower in fasting-state serum.

Reiss et al. (1970) have shown clearly, in a short study in man, that oral ingestion of phosphate supplements will decrease serum ionized calcium and increase serum iPTH levels. The data here extend this observation and confirm the postprandial changes; the main contribution lies in the permanent increase in iPTH related to the tendency for the ionized calcium to be low. Since this appeared in the fasting-state serum, it indicates a sustained effect of the phosphate loading. The significant increase in iPTH 4 hours after feeding may denote an increase in responsiveness of the glands to the stimulus.

An increase in urinary calcium as a result of a small constant dosage of PTH has been noted in normal subjects given aluminum hydroxide gel (Amphojel) (Bartter 1973). In our animals, urinary calcium increased early in the experiment when iPTH levels were minimally elevated (Laflamme & Jowsey 1972); terminally, when hormone levels were higher, urinary calcium tended to decrease. It is possible that, at the later time, PTH was affecting renal calcium excretion and causing retention of calcium while the earlier state with hypercalciuria resembled the condition of normocalcemic primary hyperparathyroidism discussed by Bartter (1973). Long-term phosphate supplementation at low levels may therefore produce a physiologic picture similar to that of osteoporosis.

The increased cortical bone resorption producing increased porosity in the adult dogs reflects the increase in PTH secretion, suggesting that in otherwise normal persons a high phosphate intake will predispose toward bone loss. Because meat has a high content of phosphate, persons on a high meat intake may be expected to become osteoporotic. This indeed appears to be true. A study of an exclusively meat-eating race of Eskimos showed a marked loss of bone density compared to a control omnivorous group, in contrast, a group on a diet of eggs, milk, and vegetables, with a relatively high calcium

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OPTIMAL CALCIUM THERAPY

A Method Affording Subjective and Objective Improvements

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Since 1947, when Albright advanced the hypothesis that osteoporosis (postmenopausal and senile) is due to deficient production of bone protein the usual treatment for this disease has been administration of anabolic steroids Although this usually leads to a subjective improvement in the patient's condition, there would seem to be no convincing evidence of an objective reduction in the osteoporosis This situation has raised doubts as to the efficacy of hormone therapy and there has been a tendency to return to the former calcium treatment, this trend was no doubt promoted by the efforts of Nordin (1960, 1961) who, in a number of articles, has pointed to the close relationship between chronic dietary calcium deficiency and subsequent osteoporosis

With the evolution of more exact methods for measuring the density of the skeleton we have over a 2 year period (1968–69) been giving intensive intravenous calcium therapy, and performing simultaneous measurements of the bone density both subjective and objective improvements have been recorded

MATERIAL

From a regular orthopaedic out patient clinic a number of patients suffering from radiologically confirmed severe osteoporosis were selected for admission and more intensive treatment In most of the patients there was compression of the vertebrae, and all complained of severe symptoms

Table 1 Sex and age distributions for the osteoporosis series

	Number	Age (years)
Men	2	48 61
Women	15	56 57 61 62, 62, 63, 63 67 68, 71, 71, 72 72, 72, 75

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igure 2 Patient using stairs ith the infusion apparatus arried in a special device ffixed to the back



Diagnostic methods

A regular clinical examination, including a case history, was carried out special attention being devoted to diseases that might affect the skeleton No bone biopsy specimens were taken Radiographs of the thoracic and lumbar spine in all cases indicated severe osteoporosis usually with compression of the vertebrae (Figure 1)

Laboratory *determinations of calcium* phosphorus alkaline *phosphatase and* creatinine in the blood were made before and after the treatment, and, so far as calcium and phosphorus are concerned also during the treatment The erythrocyte sedimentation rate and the haemoglobin were determined on admission. The urinary *sediment was examined before and after the treatment*

No systematic radiographic check was made after the treatment The patients were regularly followed clinically for at least 2 years



Figure 1 Radiograph of a patient with severe osteoporosis and compression of vertebrae

Because the pain in osteoporosis is usually located in the back it is difficult to distinguish this disease from other back conditions eliciting similar symptoms It is commonly considered that moderate osteoporosis in the spine is unaccompanied by pain this appearing only when there is a compression fracture and thus usually disappearing in a few months when the fracture has healed On the other hand it is obvious that in the case of severe vertebral osteoporosis symptoms are elicited that must inevitably be ascribed to this disease they include a feeling of weakness of the back and pain in the erect position and during loading of the spine the patient feels the need to support himself on his arms and has to rely on a corsette considerable relief is obtained in the horizontal position and for this reason the patient sometimes prefers to remain in bed These symptoms too may of course have some origin other than osteoporosis and it is clear that any attempt to appraise osteoporosis therapy solely on the basis of the patient s own assessment is most hazardous The patients selected for this study however presented more severe symptoms which were assumed to be due to the osteoporosis Between 1967 and 1970 treatment was given to 17 patients with severe osteoporosis and at the same time checks of the skeletal density were carried out The age and sex distributions are presented in Table 1

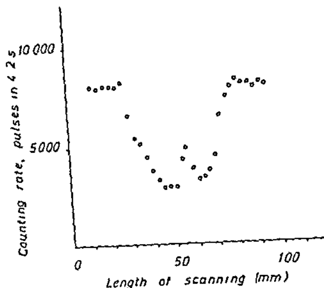


Figure 4 Measurement curve obtained in scanning over the ulna. Four such measurements are made at each examination The mean of the 3 lowest values from each curve was used

Criteria for improvement

The subjective improvement at the end of the treatment period was assessed in the usual way by discussion with the patient, avoiding any leading questions and disregarding occasional polite phrases from the patient The improvement was graded as slight significant or pronounced

An objective appraisal of the improvement was made by continuous determination of the bone density usually three times a week. In the first 10 cases the density was measured at points on both femoral condyles In the last 7 cases by scanning at a distal site on one (and the same) ulna. The density of the femoral condyles was measured by means of gamma radiation from ^{241}Am and a scintillation detector with a measuring time of one minute The radiation dose with these measurements was of the magnitude of 20 mR/hour One problem here was to ensure exact reproducibility of site and level This was facilitated by tatooing marks on the skin and providing a special device for immobilizing the knee and lower leg On each occasion an average of 3 measurements on each knee was made. The scatter with this method was of the order of 10 per cent and it was therefore difficult to record any improvement in the individual case as the expected percentage increase in calcium level was at the same or a lower level. For this reason subsequent measurements were made on the ulna For this purpose a scanning apparatus was constructed Here the radiation source was ^{125}I and a scintillation detector was also used here. The distal part of the ulna was scanned twice at two levels about 5 cm apart (Figure 3) The arm was immersed in water For each level of measurement a mean of the 3 values having the maximum

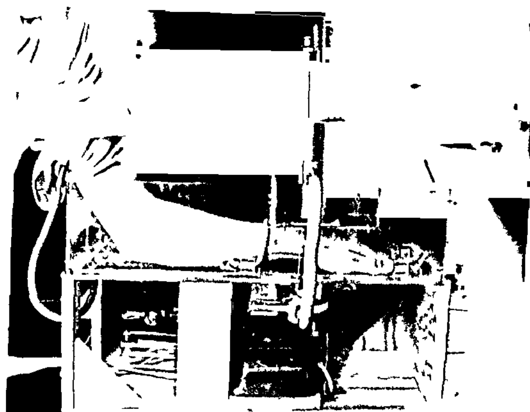


Figure 3 Apparatus for measuring the bone density in the ulna

Methods of treatment

The calcium was administered by intravenous drop infusion and as calcium glyconate (Sandoz) dissolved in a 5 5 per cent glucose solution or in cases of diabetes in isotonic saline The infusion solution contained 900 mg of calcium ions in 500 ml of prepared solution and was obtained by mixing 450 ml of the basic solution with 50 ml of a 20 per cent calcium glyconate solution Because toxic or allergic reactions are sometimes obtained when commercial preparations of calcium glyconate are used it is recommended that the original Sandoz preparation is used especially when large doses are given

The infusion rate was varied according to the individual tolerance but usually 500 ml was given over 4 hours Depending on the tolerance between 400 and 1500 ml was given daily—usually 1000 ml The treatment normally covered a period of 3–4 weeks Over the full period of treatment each patient received an average of 27 000 mg of calcium ions (range 9000—62 100 mg) Since the infusion treatment usually took the greater part of a day and it was not considered advisable to keep the patients in bed throughout the period a special support for the infusion apparatus was designed which enabled the patients to move around during the day while the infusion was running (Figure 2) For exercise they were recommended to use stairs and the cycle ergometer and where possible to participate in light gymnastic exercises

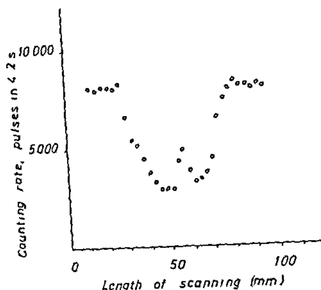


Figure 4 Measurement curve obtained in scanning over the ulna Four such measurements are made at each examination The mean of the 3 lowest values from each curve was used

Criteria for improvement

The subjective improvement at the end of the treatment period was assessed in the usual way, by discussion with the patient, avoiding any leading questions and disregarding occasional polite phrases from the patient The improvement was graded as slight, significant or pronounced

An objective appraisal of the improvement was made by continuous determination of the bone density, usually three times a week. In the first 10 cases the density was measured at points on both femoral condyles, in the last 7 cases by scanning at a distal site on one (and the same) ulna The density of the femoral condyles was measured by means of gamma radiation from ^{241}Am and a scintillation detector with a measuring time of one minute The radiation dose with these measurements was of the magnitude of 20 mR/hour One problem here was to ensure exact reproducibility of site and level This was facilitated by tatooing marks on the skin and providing a special device for immobilizing the knee and lower leg. On each occasion an average of 3 measurements on each knee was made The scatter with this method was of the order of 10 per cent, and it was therefore difficult to record any improvement in the individual case as the expected percentage increase in calcium level was at the same or a lower level. For this reason subsequent measurements were made on the ulna For this purpose a scanning apparatus was constructed. Here the radiation source was ^{125}I and a scintillation detector was also used here. The distal part of the ulna was scanned twice at two levels about 5 cm apart (Figure 3) The arm was immersed in water For each level of measurement a mean of the 3 values having the maximum

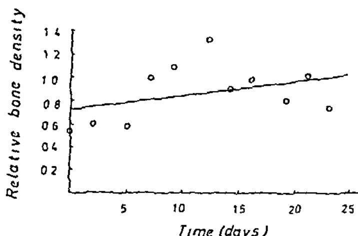


Figure 5 Patients for whom the individual measurement values of the relative bone density and the computed regression line have been drawn in

absorption was used, and as the scanning was performed twice at each of 2 levels a mean of 12 individual measurement values was obtained for each subject at each examination (Figure 4) With this method the scatter was about 5 per cent The relative calcium content was expressed in relation to measurement in water alone For the knee a variable water phantom with the same thickness at the actual femoral condyle was used

Statistical methods

For each subject a series of measurement values for the relative calcium content was obtained which covered a period from before the treatment up until treatment was completed The mean number of individual values was 6 for the knee joint and 12 for the ulna On the basis of these mean values a regression line was calculated for each subject The percentage change in the relative calcium content according to the regression line was then computed (Figure 5)

The mean percentage change during the treatment for all 17 subjects the standard error of the mean the value of t and the individual correlation coefficient of the regression lines were calculated by the usual statistical methods (Snedecor 1968)

RESULTS

As seen in Table 2 all 17 patients considered that there had been an improvement Some of the patients described the improvement as fantastic, prior to the treatment they had been more or less constantly confined to bed with back pain for up to 6 months

The percentage change in the relative calcium content and other individual data are presented in Table 3 In 15 subjects it was positive, ranging from 0 8 to 45 per cent, and in 2 subjects it was negative, with

Table 2 Subjective improvement after the calcium therapy

	Subjective improvement		
	Slight	Significant	Pronounced
Men	1	–	1
Women	3	2	10
Total	4	2	11

Table 3 Changes in bone density after treatment

Case no	Sex	Age	Duration of treatment (days)	Increase in density (per cent)*	Subjective improvement	Dose of Ca* (mg)	Measuring site
1	F	72	25	+ 14 6	+++	31 500	Femur
2	F	56	31	+ 3 9	+++	27 000	Femur
3	M	48	16	+ 13 9	+	25 200	Femur
4	F	68	14	+ 45 4	+++	18 000	Femur
5	F	75	16	+ 5 7	+++	18 900	Femur
6	F	62	27	+ 45 0	+++	25 200	Femur
7	M	61	14	– 2 9	+++	9 900	Femur
8	F	63	27	+ 1 3	+++	28 000	Femur
9	F	71	7	+ 31 2	+	9 000	Femur
10	F	57	23	+ 22 1	+++	23 400	Femur
11	F	72	25	+ 2 3	+++	62 100	Ulna
12	F	72	18	+ 2 6	+++	39 600	Ulna
13	F	62	25	+ 1 8	+	44 100	Ulna
14	F	67	18	+ 10 8	+++	34 200	Ulna
15	F	63	25	– 2 5	++	24 300	Ulna
16	F	71	7	+ 1 6	+	7 200	Ulna
17	F	61	25	+ 0 8	++	36 000	Ulna
Mean		65	20	+ 11 6		27 2 0	

* These values were obtained from regression lines for each patient and do not indicate whether there was a significant rise (fall) in the individual case

low values of 2 5 and 2 9 per cent The mean percentage change was 11 6 ± 3 8 and significant ($0\ 01 > P > 0\ 001$)

On the radiographs of the back after the treatment no definite changes in the degree of osteoporosis could be detected The calcium and phosphorus levels in the serum both before and after the treatment were within the normal ranges, and there was no evident tendency for a rise or fall during the treatment

Table 4 Side effects

The serum calcium level increased from 10—15—18 mg/100 ml (i e 5—7 5—9 mEq/l)
Hot in face and body
Fatigue, muscle weakness
Headache, malaise
Vomiting, increase in blood pressure
Disturbed balance
Impaired hearing and vision

Complications

No onset of renal calculus or haematuria was discovered during the treatment or the follow-up period In some patients small increases in creatinine concentration in plasma were recorded after the treatment, but they were within the normal range During the infusion, subjective symptoms of intolerance were reported (Table 4) In connection with such symptoms the blood calcium was often determined, and rises from 10 to 14–15 and in one case 18 mg/100 ml were noted (9 mEq/l) It is of great importance to instruct the ward staff concerning various subjective symptoms of intolerance, the first step in such cases is to reduce the infusion rate, or even to interrupt the infusion until the next day In one subject where, by error, the infusion was continued in spite of severe symptoms of intolerance (malaise, headache and vomiting) the patient had marked disturbance of balance, with difficulty in walking unsupported and marked impairment of hearing and vision, the serum calcium was then 18 mg/100 ml After discontinuing the treatment and giving cortisone intravenously all the symptoms regressed in 24 hours There was no longer any trace of the hearing or visual defect, and no explanation for them could be offered If the infusion rate is low and a lookout is kept for side effects the treatment can usually be carried out without appreciable discomfort The maximum rate could generally be found by trial the tolerated daily dose of calcium for the individual subject ranged from 800 and 2,700 mg Since significant changes in plasma calcium level occur, the treatment should be used only with great caution, if at all, in patients on digitalis therapy or with suspected or manifest arrhythmia

After-treatment and late results

After the treatment the patients were given calcium citrate and vitamins C and D by mouth (calcium 1050 mg, vitamin C 150 mg and

itamin D 3000 I U a day), usually as Casal D C ®, 10 tablets a day An orthopaedic corsette was likewise usually worn and the patients were recommended to take ample physical exercise in the form of walks and light gymnastics At the follow up checks at intervals 3–6 months the subjective improvements were usually maintained or increased, and there was no evidence subsequently of renal calculus or any other kidney disease

DISCUSSION

The improvements in the relative calcium content obtained in the individual cases with the computed regression lines for all the individual determinations showed in no case a significant rise The method error and the scatter of the individual values were too large for this The change was significant only when the results for all 17 subjects were combined

In an earlier study of clinical osteoporosis where bone biopsy specimens were taken from crista iliaca, Lindahl (1960) found that not one of 70 consecutive cases of osteoporosis revealed any sign of osteomalacia More recent investigations by Buring (1970) have shown that there is possibly reason to shift the accepted borderline between the current concepts of osteoporosis" and osteomalacia" Using a special technique not requiring demineralization of the bone specimens, it was found that osteoid tissue was considerably more common than was previously thought, probably because in conventional techniques the specimens are demineralized with the result that the milder grades of osteomalacia can no longer be detected It is possible that some of the present patients had osteomalacia that could not be diagnosed by conventional techniques There were however, no signs of osteomalacia that could be detected clinically or by laboratory tests, or that were suspected from the history

As it is inconceivable that so much new bone tissue could have been formed in the course of one month the increase in density must be ascribed in the first place to an increase in the degree of mineralization and to calcification of any osteoid tissue

In 1969 Barrier reported a good subjective effect of calcium in fusions in osteoporosis and also various laboratory data pointing to an improvement No density measurements were performed He saw no evidence of renal damage

In a group of osteoporosis patients given calcium infusions Jensen & Toft (1971) reported a case of "acute hypercalcaemic syndrome" in a patient with a plasma calcium level of 20 2 mg/100 ml The patient, who was obviously in a poor general state, recovered in 4 days when cortisone and phosphate infusions were supplied The authors recommend that when such treatment is given it should be checked that the glomerular filtration rate is normal and that the plasma calcium level has returned to normal after the previous infusion

The calcium treatment should, of course, be given only with the greatest caution, if at all, to patients with impaired renal function, but experience shows that subjective symptoms are the best warning signal of a too intensive treatment and hypercalcaemia, and care should be taken to instruct the staff and the patient about the symptoms of intolerance.

In view of the antagonism between calcium and potassium, care is probably also indicated in the case of patients where there is reason to suspect disturbance of the potassium metabolism—for instance, after treatment with hypertensive agents

SUMMARY

Large amounts of calcium (on average 27,000 mg given over 4 weeks) were administered as an intravenous infusion to patients with severe osteoporosis The patients reported a marked improvement, and a mean rise in the bone density of 11 6 per cent was recorded in measurements on the femoral condyles or the distal part of the ulna by means of gamma radiation from ^{125}I and a scintillation detector This objective improvement is statistically significant (0 01 > P > 0 001)

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HEALING IN DENERVATED BONES

A Navarro Quilis & A Peiró González

Accepted 21 x 74

In children suffering from myelomeningocele who needed orthopaedic or surgical correction of the lower extremities we found an increased number of fractures of the femur and tibia and an anomalous type of repair (fast and with abundant callus production on many occasions) (Navarro, in preparation)

These fractures are found not only in children with myelomeningocele, but also in people with paraplegia due to other causes, e g subdural haematoma (Caffey 1946, Alliaume 1950), spinal fractures associated with cord lesion (Katz 1953, Robin 1965), lumbosacral root avulsion, transverse myelitis (Jeannopoulos 1954) and cord tumours (Robin 1965)

We could not obtain clear conclusions due to the influence of many factors the delay in recognizing the fractures (due to lack of sensation), the different levels of the fractures, and the variable ages of the patients However, it was evident that the atrophic bone with a supposed low "metabolic flux" or turnover repaired well and quickly

In an attempt to clarify these factors we made an experimental model choosing the rat because of the facility of obtaining animals of the same sex, age, weight and genuticity, and because it had been already used to study the repair of fractures in denervated limbs (Smith & Dunsford 1955, Hulth & Olerud 1965) and also because it had been shown that in bone atrophy following denervation, the turnover was variable with different periods of immobilization (Landry & Fleisch 1964) We studied histologically the fracture and bone defects produced for the same periods of denervation as those used by Landry & Fleisch (1964)

MATERIAL AND METHODS

Animals

The animals used were young male Wistar rats weighing between 80 and 110 g Eighty rats, divided into two main groups were used

I) Complete fractures (64 rats)
a) Femoral series
Fracture of the denervated femur (16 rats)
Fracture of the normal femur (16 rats)
b) *Metatarsal series*
Fracture of the third denervated metatarsal (16 rats)
Fracture of the third normal metatarsal (16 rats)
II Bone defects (16 rats)

The bone defects were created in both femora and tibiae of the same animal

Technique

All the animals had a denervation of the right hind leg *Under ether anaesthesia* and through a latero posterior approach the primary rami L 3 L-4 L-5 L-6 and S 1 were found between the insertion fibres of the psoas muscle Five millimeters of each primary ramus were resected

The fractures were all produced through a small incision cutting the bone through with small scissors at the level of the junction of lower and middle third of the femur and the proximal third of the third metatarsal the bone defects were made with small bone biting forceps in the femoral metaphysis and the tibial shaft in every case the bone marrow was able to be seen through the defect

Timing of the fracture and bone defects These were produced immediately two four and seven weeks after the denervation



Figure 1 X ray appearance (at seven weeks) of a femoral fracture produced four weeks after denervation

Study of the repair

The repair was studied at one two four and seven weeks after the fracture both radiographically and histologically (Figure 1)

The first fracture series served for the study of the fracture repair in bone without immobilization The second fracture series served for the study of the fracture repair in conditions of immobilization (splintage of the second and fourth metatarsal bones)

The bone defects were made in both legs of the same animal because the animal could manage well in spite of the defects

Histological technique Ten per cent formol solution was used as a fixative Decalcification with EDTA Wax paraffin inclusion Six micron thick slices and haematoxylin eosin (H E) staining

Prior to the fixation the specimens were radiographically studied

Difficulties

Many more rats than the ones we used were operated on A few were not studied due to operative infection but most rats were not used because of trophic ulcers in the feet due to lack of sensation and in many cases this was followed by autophagic phenomena This forced us to change the animal cages for ones in which the walls and floors were completely smooth

RESULTS

Femoral Fractures

First group Fractures produced at the same time as the denervation

Week 1 The marrow reaction is the same in both femora There is no subperiosteal reaction with bone or cartilage formation The newly formed tissue is less differentiated on the denervated side

Week 2 The periosteal reaction is quite similar on both sides, but on the normal side the cartilage formation is more noticeable Much new vessel formation is observed in the callus

Week 4 On both sides the fracture is united by bone at the periphery of the callus Again the central part of the callus shows a very rich blood supply on the denervated side and this is not present on the normal side

Week 7 Advanced union is observed from the periosteal bone Ossification is equal on both sides Bone response is equal on both sides

Summary The bone response is much slower on the denervated side up to the second week but from here onwards it increases and from the fourth week both processes look quite similar The atrophic

* By bony union we mean lack of mobility of the fragments and a histological presence of a bridge of bone between the fragments

side has *less* cartilage formation and a *much richer* blood supply to the callus

Second group Fracture two weeks after denervation

Week 1 Marked bone formation in the marrow cavity as on the normal side and similar to the first *group Good* periosteal bone formation, greater than on the normal side and in the first group The bone formation is more abundant in the proximal fragment

Between the fragments a large fibro-cartilaginous metaplasia is observed

Week 2 The repair is much more advanced on the atrophic side The *periosteal bone* formation is abundant with bony bridges and areas with ossification fronts and osseous cartilaginous metaplasia The osteoclasts are more abundant on the atrophic side

Week 4 Bony union is seen The periosteal bone is completely remodelled with a new cortex formation

Week 7 Complete bony union is obser*ved on the atrophic side but* not on the normal side

Summary The repair process is much more advanced in the denervated femur

Third group Fracture four weeks after denervation

Week 1 A large amount of bone formation on the atrophic side but not so abundant as in the second group

Week 2 Similar to the normal side, but with less cartilage formation, and a greater number of osteoclasts

Week 4 Complete bony union from the new periosteal bone More advanced process than on the normal side Excellent turnover judging from the richness in osteoclasts and osteoblasts (Figures 2 and 3)

Week 7 More solid union than on the normal side but presenting slight mobility (manual)

Summary The bone formation and the remodelling are *very good* and greater than on the normal side

Fourth group Fracture seven weeks after denervation

Week 1 There is no bone formation The fracture gap is entirely cartilaginous

Week 2 Lamellar bone is already *formed and a very marked number* of osteoclasts All this indicates a very good remodelling process, more active than on the normal side

Week 4 Cartilaginous union with ossification fronts on both sides

Week 7 Cartilaginous union with some areas of non union on the normal side



Figure 2



Figure 3

Figures 2 and 3 Magnified views of a slide showing the normal and denervated sides of a femoral fracture at four weeks

Summary On the atrophic side there are some bony bridges mixed up with the cartilaginous callus

The process is quite similar to the normal side up to the second week, but after the fourth week on the atrophic side the union is complete

Summary of the Femoral Series

None of the groups had less reaction on the atrophic side, but in the first group there was a lazy reaction during the first week

In all the groups there was a smaller amount of cartilage formation on the atrophic side The remodelling was good in every group, with a good lamellar bone formation

The healing was faster and stronger on the atrophic side of the second third and fourth groups

Fracture of the Third Metatarsal Bone

First group Fracture produced at the same time as the denervation

Week 1 There are no morphological differences between the two sides

Week 2 Periosteal bone formation Cartilage formation changing to bone between the two fragments The process of repair is more advanced in the denervated side

Week 4 The fracture of the denervated limb is completely united There is lamellar bone formation the bone of periostic formation has been completely remodelled

On the normal side the fracture is not yet united and there is a good deal of cartilage formation

Week 7 Both fractures are united

Summary There is a greater bone reaction and a faster healing process on the atrophic side than on the normal one

Second group Fracture two weeks after denervation

Week 1 There is no difference in the two sides A large amount of periosteal reaction

Week 2 Quite similar processes in both normal and denervated sides

Week 4 Process is much more advanced on the atrophic side than on the normal one (Figure 4)

Week 7 Bony end separated by a cartilage bridge which is very thin on the denervated side and much thicker on the normal side

Summary The repair process is more advanced on the atrophic side but bony union is not seen on either side

Third group Fracture four weeks after denervation

Week 1 Bony metaplasia from granulation tissue in the fracture gap is observed on the atrophic side This is not seen in any other group

Week 2 Periosteal bone formation more abundant than in the former groups

Week 4 Quite similar to the second group The periostic reaction has subsided and there is a central bony bridge



Figure 4 Shows the thin gap filled with cartilage and the new bone formation in the medullary canal (× 78 75)



Figure 5 Shows a bony bridge and a central gap filled with cartilage (× 31.25)

The difference on the normal side is that the periostic bone still persists showing that the union is perhaps not so advanced

Week 7: Peripheral bony bridges are seen on the atrophic side, showing an advanced healing process (Figure 5)

Summary: Greater reaction during the first two weeks on the atrophic side. More rapid union on the atrophic side

Fourth group: Fracture produced seven weeks after denervation

Week 1: Periostic reaction with bone formation in both cortices, on the atrophic side. This was not observed in any other group.

Week 2 The callus formation is quite similar to that observed at four weeks in the second and third groups on the atrophic side

Much more advanced process than on the healthy side

Week 4 Not much difference from the former stage

Week 7 There is no bony union yet, but there is a cartilaginous bridge Lamellar bone formation

Summary A faster healing process than in other groups, but without union Bigger fracture gap?

Summary of the Metatarsal Series

In groups one and two, the reaction was equal on both sides, during the first week After that, the atrophic side reacted with a quicker union that ended with a bony union in the first group and a thin cartilaginous bridge in the second group

In groups three and four, the response was stronger on the atrophic side during the first two weeks in the following weeks the process of union was more rapid on the atrophic side, but not so complete as in the first group Is this because of a greater fracture gap or a greater comminution of the fracture? The remodelling was good with an intense osteoclasia

The greatest response was between four and nine weeks after denervation

The amount of cartilage was quite similar on both sides and much less than in the femoral series

Study of Bone Defects in Cortico Cancellous Bone (Femur)

First group Bone defect produced immediately after denervation

The healing process is less marked up to the second week on the atrophic side equalizing later on with the normal side There is no cartilage formation

Second group Bone defect produced two weeks after denervation

On the atrophic side a more advanced healing process is observed with a difference of at least one week but there is less bone formation

There is no cartilage formation unlike the normal side and on both sides there is a marked periosteal bone forming reaction of similar intensity

Third group Bone defect produced four weeks after denervation

The bone formation is more rapid on the atrophic side up to the second week but from then to the seventh week the reactions tend to equalize



Figure 6 Seven weeks after denervation Atrophic femur Callus at two weeks Observe the new bone in the medullary cavity communicating through the gap with the outer periostic bone No cartilage (× 20)

On the normal side a marked periosteal reaction and cartilage formation is observed, but not on the atrophic side

Fourth group Bone defect produced seven weeks after denervation The reaction is quite similar up to the second week but between the second and the seventh week the bone defect is completely repaired on the atrophic side while it is still remodelling on the normal side (Figure 6)

The quantity of bone and cartilage formation is similar on both sides

Overall Assessment

Cartilage On the atrophic side cartilage is seen only in the fourth group On the normal side there is minimal cartilage formation except in the third group where it is abundant

New bone formation Very good formation in the second and fourth groups but much less in the third group taking the normal side as control

Quickness of repair At all stages the atrophic bone shows repair equal or superior to that of the normal bone The periods in which the repair is superior vary according to the time of atrophy In the second group the repair is quicker in every instance with a more advanced remodelling In the third group it is greater up to the second week equalizing later In the fourth group it is equal up to the second week being greater later on (Figure 7)



Figure 7 Two weeks after denervation Four weeks after the defect was created Normal femur The defect is covered with new bone (× 20)



Figure 8 Four weeks after denervation Atrophic tibia. Callus formation at two weeks Shows no cartilage formation and abundant new bone (× 20)



Figure 9 The same group as Figure 8 Denervated tibia. After seven weeks of repair Observe the great quantity of bone plugging the gap (× 20)

Study of the Bone Defects in Cortical Bone (Tibia)

First group: Bone defect produced immediately after denervation. Equal repair during the first week, but from here onwards the atrophic side shows a faster and more complete repair.

Second group: Bone defect produced two weeks after denervation. The stage of repair looks the same. There seems to be less new bone on the atrophic side. There is no cartilage formation (Figures 8 and 9).

Third group: Bone defect produced four weeks after denervation. The normal side has a similar repair to the denervated one up to the second week, but from here onwards the defect is repaired more quickly and with more bone on the atrophic side. The cartilage formation is minimal on both sides.

Fourth group: Bone defect produced seven weeks after denervation. The repair process is much faster on the atrophic side. There is no cartilage formation, as there is on the normal side; however, this produces more new bone. A double cortex is observed on the atrophic side.

Overall Assessment

Cartilage. The atrophic side produces practically no cartilage to repair the bone defect. The normal side produces a large amount of cartilage in the fourth group.

New bone formation. The atrophic side has a richer new bone formation than the normal side in the third group. In the other groups there is less on the atrophic side (Figure 9).

Time of repair. The time taken for repair on the atrophic side is never longer than on the normal side, being equal in the second group, shorter in the fourth group, and equal up to the second week, and shorter from the second to the seventh week in the third group, as happens in the fourth group of the defects in cortico-cancellous bone.

In general, similar phenomena are observed in both the cortical bone and the cortico-cancellous bone, but at different periods of the bone atrophy.

DISCUSSION

Our results compared with the ones obtained by Smith & Dunsford (1955), Hulth & Olerud (1965) and Reyes Cunningham et al. (1971) (The present work was finished before this last paper was published.)

Smith & Dunsford (1955) arrived at the conclusion that there was

delayed healing in fractures of the tibia produced thirty five days after the denervation of the limb, with a sciatic nerve avulsion, and that this delayed healing was due to the bone atrophy We shall discuss this later

Amongst the other factors put forward by the same authors we can list

– *Smaller calibre of* the vessels in the denervated bone This is not so as shown by Kemp et al (1947), Imig et al (1953), Geiser & Trueta (1958), Hulth & Olerud (1960, 1961), Baungartl et al (1958), Ferguson & Akahoshi (1960)

– Less soft tissue, especially muscle

– The marked displacement of the fracture of the control limb compared with the denervated one (this argument would be acceptable if the authors were defending the opposite viewpoint)

These authors studied fracture healing only radiographically

Hulth & Olerud (1965) also studied fracture of the tibia in rats following a motor sensory mixed and peripherial denervation They found exuberant callus formation at two weeks in all the series The fracture was produced one week after denervation Their results are in agreement with ours

In the group in which the denervation is sensory or mixed, a greater quantity of cartilage is found We found less cartilage in the denervated side perhaps in cases with sensory denervation, there is a greater amount of cartilage due to the use of the insensitive limb, but in our cases with a mixed denervation the limb is completely useless, and in the bone defect series in which there is no mobility there is less cartilage formation in the denervated side this favours the argument that the mobility is the cause of the cartilage formation

Boyes *Cunningham et al (1971) found delayed callus formation* and scanty mineralization after radiological and histological studies They studied callus formation of fractures produced at the time of denervation and used an intramedullary rod which very probably alters the vascular pattern of the bone

As is the case with fractures, the results in denervated skin are contradictory Muren (1953) says that denervated skin heals normally, but Sandberg & Zederfeldt (1961) do not agree with these findings and say it shows a diminished tensional resistance

Our work is more complete than the above-mentioned studies, because we studied bone healing after different periods of bone atrophy

Our Findings

In fracture of the femur:

- Less cartilage formation than on the normal side
- More adequate blood supply to the fracture gap tissue
- Quicker and more complete union in every group. All the denervated groups showed union at between four and seven weeks, however, in the normal group there was no union in the second, third and fourth groups
- The bone resorption is greater on the atrophic side judging by the number of osteoclasts
- Bone remodelling is as good as on the normal side, with cortical and lamellar bone formation

In the fracture of metatarsal bone

- The amount of cartilage is similar on both sides, but much less than in the femoral group
- Quicker union, with greater bone formation and bone absorption, on the denervated side

In the femoral bone defect

- There is less cartilage on the atrophic than on the normal side
- There is more new bone formation on some of the atrophic sides, but not on all
- The repair is always quicker on the atrophic side

In the tibial bone defect

- *The findings are similar to the femoral bone defect but at different* periods of bone atrophy

Our results compared with the ones obtained by Landry & Fleisch (1964)

Landry & Fleisch (1964) *found that* bone atrophy *following* denervation can be divided into three periods

a) During the first two weeks, bone formation is diminished
b) From two to seven weeks bone formation and resorption increase, in other words the turnover or "metabolic *flux*" *is* increased
c) At five months bone formation is again below normal, showing the lowest values in the whole study

We agree with these findings, but we could not clearly separate the same periods due to the intermingling of the atrophy and fracture. We

observed, however, that between the ninth and fourteenth weeks after denervation bone formation was not as good as in former weeks.

Consideration of the diminished cartilage formation in the femoral series of the denervated limb

We can explain the diminished cartilage formation in the denervated femora in two ways

1) The lesser mobility of the fragments

2) The greater blood supply, due to new blood vessel formation and more rapid blood flux in the atrophic bone (Kemp et al 1947, Imig et al 1953, Geiser & Trueta 1958, Ferguson & Akahoshi 1960)

It seems that the movement of the fracture fragments does not permit the advancement of the new blood vessels and so hinders healing This lack of blood supply would create a low oxygen tension and so enhancement of cartilage formation, a fact demonstrated by Bassett (1963) who showed that cells with bone forming capacity are very sensitive to variations in oxygen level

This fact explains clearly why there is less cartilage formation in the atrophic femur, but not in the metatarsal bone Perhaps the vascular changes are not so marked in the foot bones, which are surrounded by much less connective tissue

It is more logical to explain the differences between femur and metatarsal bone, using the argument that excessive movement is the principal cause of cartilage formation The denervated limb is useless and dragged behind by the animal, and so the femoral fragments have very little movement The healthy limb has to be used in spite of pain during the first few days

In the series of the bone defects, there is also less cartilage on the atrophic side, which is in favour of the mobility argument

Study of the bone remodelling process

We have observed a good formation of primitive bone, lamellar bone and new cortical bone These findings support the histological observation of Calto (1967) in one of our patients with myelomeningocele (Navarro, in preparation), in whom we found normal bone formation Therefore we cannot agree with Eichenholtz (1963) "It seems that (the callus) never progresses to compact mature bone, but it seems to remain in limbo between fibre primitive bone and the adult cortical one"

Our Findings

In fracture of the femur·

- Less cartilage formation than on the normal side
- More adequate blood supply to the fracture gap tissue
- Quicker and more complete union in every group All the denervated groups showed union at between four and seven weeks, however, in the normal group there was no union in the second, third and fourth groups
- The bone resorption is greater on the atrophic side judging by the number of osteoclasts
- Bone remodelling is as good as on the normal side, with cortical and lamellar bone formation

In the fracture of metatarsal bone

- The amount of cartilage is similar on both sides, but much less than in the femoral group
- Quicker union, with greater bone formation and bone absorption, on the denervated side

In the femoral bone defect

- There is less cartilage on the atrophic than on the normal side
- There is more new bone formation on some of the atrophic sides, but not on all
- The repair is always quicker on the atrophic side

In the tibial bone defect

- The findings are similar to the femoral bone defect but at different periods of bone atrophy

Our results compared with the ones obtained by Landry & Fleisch (1964)

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a) During the first two weeks, bone formation is diminished
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CONCLUSIONS

1) In fracture of a denervated femur, we found less cartilage formation, a greater blood supply, a quicker and more complete union and greater bone resorption
2) Bone remodelling is normal
3) In the fracture of the metatarsal bone, we found the same amount of cartilage formation on both normal and denervated sides however, the amount was much less than in the femur
4) The study on bone defects confirms the cyclic variations of bone turnover in atrophic conditions
5) The differences in turnover depend on the type of bone (cancellous, cortico cancellous, cortical) and the time of atrophy
6) These findings may explain the differing results found in the literature

SUMMARY

A study of the healing of complete fractures and bone defects was made in the rat with a denervated limb The femoral and metatarsal bones were used to compare the healing of mobile and immobilized fractures The metaphysis of the femur and the shaft of the tibia were used to study differences in healing of bone defects

Various periods of bone atrophy were used to study how the behaviour of repair is altered by the degree of atrophy

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THE BONE MINERAL CONTENT IN THE FOREARM OF WOMEN WITH COLLES' FRACTURE

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Accepted 23 ii 74

Buhr & Cooke (1959) pointed out the rather specific epidemiological pattern of fracture of the distal end of the forearm This pattern was studied in greater detail by Alffram & Bauer (1962) and it was demonstrated that the risk of fracture in women over the age of 40 increased dramatically Later, Alffram (1964) demonstrated that women with fracture of the upper end of the femur also more frequently than could be expected from the incidence of the population at risk had sustained fracture of the distal end of the forearm

Bauer (1960) interpreted data on fracture incidences and suggested that fracture of the distal end of the forearm is an early symptom and fracture of the upper end of the femur a late symptom of disturbed skeletal metabolism

The objective of the present study was to compare the bone mineral content of the forearm in women with Colles' fracture and in a control sample of women without fracture

MATERIAL

Sixty four women were selected who had sustained a fracture of the distal end of the forearm (Colles fracture) Only women in whom the fracture was caused by falling from the standing position or other lesser trauma were included In addition 64 women without fracture were measured The ages of the fracture and control cases were 63 6 ± 10 7 and 63 5 ± 11 1 respectively All except 5 fracture cases and 6 controls were post menopausal

No women were included who had previous fracture or other pathological condition in the upper limbs including the shoulders who had undergone gastric

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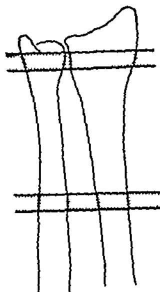


Figure 1 The sites of the rectilinear scans

surgery or who had kidney disease liver dysfunction intestinal dysfunction alcoholism or other conditions known or suspected to be related to bone mineral loss

In the control cases the bone mineral content was measured in both forearms In the fracture cases the bone mineral content was measured within a week of the occurrence of fracture In 19 cases both forearms were measured which required anaesthesia in the remaining cases only the uninjured forearm was measured

METHODS

Vital Statistics

Height weight age at menarche age at menopause and parity were recorded

Bone Mineral Content

The bone mineral content was measured by the method of gamma absorptiometry The measuring device has been described previously (Nilsson & Westlin 1972 Westlin 1974) Two rectilinear scans were made across the ulna and the radius at 1 cm—*distal* measuring site—and 6 cm—*proximal* measuring site—from the distal end of the ulna located by palpation (Figure 1) The results were expressed in mg per cm² and represent the average thickness of bone mineral in the pathway of the beam in the radius plus the ulna

Width

As well as the digital representation of the mineral content in the forearm the width of the ulna and the radius facing the beam and the width of the marrow

cavity can be measured on a graphical tracing of the scan (Westlin 1974). From the tracings the total width of the radius and the ulna, the total width of the marrow cavities of the two bones and the total cortical thickness of the two bones were calculated.

Size and Force

The length of the ulna from the tip of the olecranon to the distal end, and the maximum circumference of the forearm in the relaxed position were measured. Also, the force of the hand grip was measured—the women were asked to compress a rubber bulb and the pressure in kg/cm^2 was recorded by a manometer; the average of 3 attempts was used.

RESULTS

The height was slightly and almost significantly greater in the fracture cases; there was no significant difference in weight (Table 1). Of the GOB variables only parity differed slightly between the fractures and controls; the difference was not significant.

The bone mineral content was reduced by about 7 per cent in the fracture cases as compared to the control cases with the same reduction in both measuring sites. However, the difference was significant only in the proximal measuring site on the shafts of the two bones (Table 2).

From the total (subperiostal) width and the width of the marrow cavities of the two bones the combined cortical thickness of the bones was calculated (Table 2). The cortical thickness was reduced by about 13 per cent. This reduction may explain completely the reduction in bone mineral content and when the cortical thickness was corrected for

Table 1. Vital statistics

Variable	Fracture No	Fracture Av ±SD	Control No	Control Av ±SD	P*
Age	64	63.5±10.7	64	63.4±11.1	0.9 > P > 0.8
Height (cm)	57	163.7± 6.2	54	162.1± 6.2	0.05 > P > 0.02
Weight (kg)	60	65.0±10.4	61	66.3±10.1	0.9 > P > 0.8
Menarche age	64	14.1± 1.4	62	14.4± 1.7	0.3 > P > 0.2
Menopausal age	58	48.6± 5.8	55	49.1± 4.5	0.7 > P > 0.6
Years after menopause	58	16.9± 9.8	55	17.0±10.2	0.8 > P > 0.9
Parity	63	1.41± 1.27	62	1.85± 1.56	0.1 > P > 0.05

* T-test of pairs (pair = women with fractures and age matched controls)

Table 2 Mineral content and bone widths

le	Fracture No	Fracture Av ±SD	Control No	Control Av ±SD	P*
al content distal (mg/cm²)	64	231 ±70	64	249 ±74	0 2 > P > 0 1
content prox (mg/cm²)	64	430 ±77	64	464 ±81	0 01 > P > 0 001
l width prox (mm)	64	28 9± 2 2	64	29 2± 2 0	0 6 > P > 0 5
ow width prox (mm)	64	16 3± 2 3	64	15 7± 2 4	0.3 > P > 0 2
cal thickness prox (mm)	64	12 6± 1 9	64	13 4± 1 7	0 01 > P > 0 001
width distal (mm)	64	43 2± 5 5	64	43 7± 3 4	0 8 > P > 0 7

*est of pairs (pair = women with fractures and age matched controls)

(covariance analysis with cortical thickness as the covariant factor) there was no longer any difference between the bone mineral content in the proximal measuring sites

Finally, the size and the force measurements (Table 3) indicate a decreased circumference of the forearm of the fracture cases as compared to the control cases The small difference in force of the hand was, however, not significant

DISCUSSION

From the data of the control women it could be demonstrated that there is a non-systematic left-right variation which is relatively more marked in the distal measuring site (Figure 2) It must, therefore, be assumed that in women without fracture the bone mineral mass of the left and the right forearms do not differ Thirty-two of the fracture cases had injured their left arm, in these cases the uninjured right arm was measured and assumed to represent the bone mineral mass of the forearms of these patients In the remaining 32 patients the opposite

Table 3 Size and force of the forearms

Variable	Fracture No	Fracture Av ±SD	Control No	Control Av ±SD	P*
Ulnar length (cm)	56	25 4±1 5	64	25 6±1 1	0 4 > P > 0 3
Arm circumference (cm)	56	24 5±2 1	64	25 4±1 9	0 02 > P > 0 01
Force kg/cm²	55	0 53±0 17	64	0 55±0 20	0 4 > P > 0 3

* T test of pairs (pair = women with fractures and age matched controls)

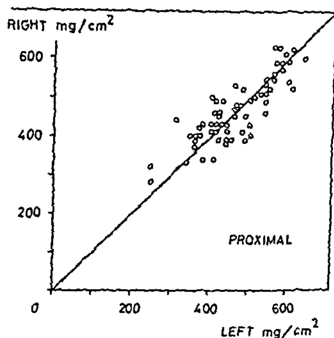


Figure 2 a

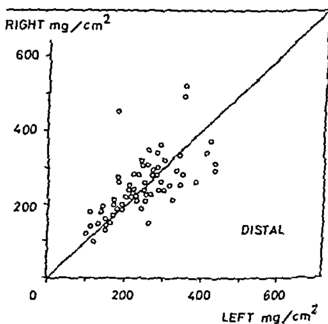


Figure 2 b

Figure 2 The relationships between the bone mineral contents of left and right forearms in control women

Table 4 Mineral mass of the contralateral arm in fracture cases (mg/cm²)

	Left		Right	
	No	Av ±SD	No	Av ±SD
Proximal	32	434±73	32	426±82
Distal	32	236±74	32	226±66

was the case A comparison of right-sided and left-sided measurements is demonstrated in Table 4 There was no difference between left arms and right arms In addition, measurements were available from the day of the fracture in 19 of the patients in whom the proximal site of the fractured forearm was measured under anaesthesia The value (443 ± 108 mg/cm²) did not differ significantly from the values of the uninjured forearms of the fracture cases

It must therefore, be assumed that the value of bone mineral content of the uninjured forearm is a fairly accurate parameter of the injured arm and that there is no significant difference between the two

A difference in mineral mass between the bones of injured and uninjured women may be due to a difference in size, an increased porosity, a reduced mineralization, and—in diaphyseal bone—to differences in the width of marrow cavities With regard to the size of the bones it must be concluded from our data—the widths of the bones on the two measuring sites and the length of the ulna—that the bones of the forearm are of the same size in women with and without Colles' fracture

It should be stressed that the measurements of the cortical thickness, as calculated from the widths obtained from the tracings of the scans, are not very accurate although they may be more accurate than measurements from radiographs on this site (Westlin 1974)

Nordin (1966) demonstrated that the metacarpal index, based on measurements from radiograms of the second metacarpal, was lower in women with Colles fracture than in normal controls This finding is confirmed in the present study also in the fractured bone itself, the radius there is evidence of thinning of the cortices and in fact the significant reduction of bone mineral content in the shafts of the radius and the ulna can be completely explained by the cortical thinning The probable difference between fracture and control cases in bone mineral content in the distal measuring site, however, can probably only be explained by an increased porosity

Is the difference in bone mineral mass demonstrated in this study sufficient to cause an increased risk of fracture? The difference amounted to no more than 7 per cent and was not even significant at the fracture site. Data, experimental as well as clinical, support the concept that a small loss of bone mineral may cause a disproportionately greater loss of bone strength (Voss et al. 1961, Beck & Dunbar 1967, Nilsson & Smith 1969). From the data of the control women in the present study it can be calculated that during the fifth through the eighth decade of life the average loss of bone is 9–10 per cent per decade. This figure is supported by other data from our laboratory and by other investigators (Oeser & Krokovsky 1963, Meema & Meema 1963, Smith & Rizek 1966 and Garn et al. 1967). Therefore, in relation to the rapid changes with age of the risk for Colles' fracture in women, a loss of 7 per cent translated into years in the fifth or sixth decade of life could be associated with a quadrupling or more of the risk of fracture (Buhr & Cooke 1959, Alffram & Bauer 1962). Ideally, each case of fracture in this study should have been compared to a woman who had been subjected to an adequate trauma like falling to the ground from the standing position, without sustaining a fracture, in analogue with the data of Vose & Lockwood (1965) in their study of the bone mass in individuals with femoral neck fracture. The control group probably contains individuals with the same fracture risk as those of the fracture group with the exception that they have not yet had their fracture. This, also, should be kept in mind when the bone mineral mass of the two sets is compared.

Nilsson (1970) demonstrated that while the femoral neck fracture was associated with spinal osteoporosis (measured as shortening of the trunk) and with weight reduction, fracture of the forearm was not. This is supported by the present study in that there is no significant weight difference, and the fracture cases were on the contrary somewhat taller. On the other hand as far as can be seen from the measurements of the forearm with an intact muscle force and decreased forearm circumference the fracture cases may be somewhat leaner. The same has been demonstrated in alcoholics (Nilsson & Westlin 1973).

The parity observed in the fracture cases was suspiciously low and was caused by an increased number of nulliparous women in the sample. The difference was, however, not significant. When the sample size was doubled including also women with Colles' fracture who were not included in the present study and comparing to the population data

of Malmo (Bjerre 1974) the difference remained statistically non-significant Alffram (1964) could not demonstrate any differences between women with and without femoral neck fracture in this respect

Otherwise, however, few differences could be demonstrated between the two sets, women with and without Colles' fracture A 7 per cent loss of bone mineral content mainly due to cortical porosity of the forearm may, however, in the light of the evidence from the literature, result in sufficient change in quality to cause a substantial increase in the risk of fracture

SUMMARY

The bone mineral content in the forearms was measured by the method of gamma absorptiometry in 64 women with Colles' fracture and 64 age matched women without fracture The bone mineral mass was reduced by about 7 per cent in the shafts of the radius and ulna proximal to the fracture and also but not quite significantly in the trabecular structures of the distal end of the forearm, the fracture site The reduction, although small, may well cause an increased risk of fracture when the rapid change of fracture incidence with age is taken into account

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CERVICAL SPINE INJURIES

A Clinical and Radiological Follow up Study, in Particular with a View to Local Complaints and Radiological Sequelae

ERIK HORLYCK & MOGENS RAHBEK

Accepted 14 iii 74

Injuries to the cervical spine have been the subject of numerous studies (Blikra & Ringkjøb 1969 Durbin 1957, Norton 1962, Rogers 1957, Schneider & Kahn 1956) Most of these studies were primarily concerned with the prognosis of any associated injury to the spinal cord

The prognosis in lesions of the cervical spine without injury to the cord has been discussed less frequently (Cheshire 1969, Janes & Hooshmand 1965 Rogers 1957) Cheshire (1969) dealt extensively with the problems concerning stabilization of spinal fractures with conventional treatment

In our series of patients with lesions of the cervical spine, who were treated mainly with conventional cranial extension, we have carried out clinical and radiological follow up studies, in order to evaluate subjective complaints and X ray changes caused by the spinal fracture itself

MATERIAL AND METHODS

The study comprised 71 patients with cervical spine injuries admitted to the Neurosurgical Department Copenhagen County Hospital in Glostrup over a 3½ year period from April 1966 to October 1969

Age and sex distribution of the primary group appear in Figure 1

Figure 2 shows the number of lesions found at various levels of the cervical spine The distribution by level and frequency of lesion corresponds to reports by Durbin 1957 Norton (1963) and Rogers (1957) as does the age curve which shows a preponderance of very young persons

Seventy five per cent of the spinal injuries were caused by traffic accidents In 12 of the patients the cervical spine lesions occurred at two or more levels Twenty patients had the lesion at C1 2 including the underlying disc and in 51 patients the lesion was at level C3–7

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with considerable compression or crushing of the anterior structures of the cervical spine and 11 patients had extension lesions, where either isolated fractures of the posterior structures of the spine were apparent, or where reliable data were available concerning extension trauma

At the level of C3-7, 20 cases of total or severe incomplete tetraplegia were found among 51 patients Four out of 5 patients with severe comminuted lesions of the cervical body (bursting fractures) had complete or severe incomplete lesions of the cervical cord Otherwise, the present series did not show any correlation between type of fracture and lesion of the spinal cord

Seven patients with total tetraplegia survived, one of them recovered completely In the remaining patients, the condition was stationary On the other hand, patients with incomplete tetraplegia presented varying improvement

At the level of C1 2, there was one case with a doubtful lesion of the spinal cord presenting as hyperreflexia Apart from this case, no patients with lesions at this level had any signs of lesion of the cord

The treatment of cervical injury consisted of immobilization In most of the cases conventional immobilization by cranial extension was applied, using either Blackburn s or Crutshfield s tongs In two cases of anterior luxation reposition was done immediately after admission Anterior fusion was applied in one case, because the patient refused cranial extension Cranial extension was normally maintained for 4 to 12 weeks

When mobilization was commenced radiographic check up of the cervical spine was usually carried out Sixteen of the original 71 patients died during the stay in hospital or immediately after Four died because of tetraplegia associated with respiratory insufficiency 8 because of complicating cervical concussion, and 4 because of other complicating major injuries among them lesions of the chest Also in the series reported by Stadaas & Johannesen (1970), persistent respiratory distress and complicating cerebral concussion resulted in a very high mortality

Follow-up Study

This was made between 3 and 6 years after injury The clinical follow up included 48 patients 45 of whom also underwent X ray examination of the cervical spine Three patients had died before the follow up study In none of these cases was the cause of death connected with the cervical injury As regards two of the patients information was obtained second hand and two patients could not be traced Thirty seven of the 48 patients who had been followed up had been treated with cranial extension for 4 to 12 weeks and of these, 31 had been treated for 9 to 12 weeks The remaining 11 patients had been treated with cervical brace or brief recumbency

At the check up the patients were asked about local complaints and neurological symptoms A neurological examination was also performed and the data given by the patients were assessed

The radiographs comprised AP lateral and oblique views of the cervical spine, supplemented by lateral views with the spine in extension and flexion

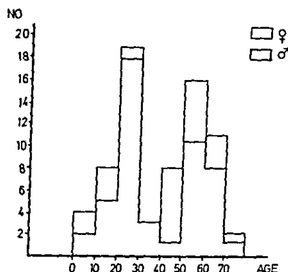


Figure 1 Cervical spine lesions Age and sex distribution in 71 patients

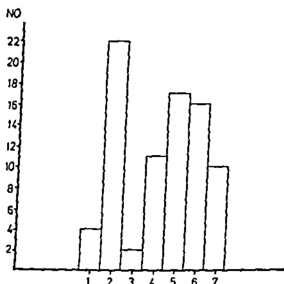


Figure 2 Distribution of cervical spine lesions in 71 patients 12 patients had lesions at two or more levels

The studies made by Roaf (1960) and Beatson (1963) on isolated cervical specimens and Holdsworth s study published in 1963 have contributed greatly to the understanding of the mechanism in lesions of the cervical spine

Spinal lesions of C 3–7 were classified according to the above studies and were correlated with the case histories available and with the presence of skin lesions on the head In a clinical series such a classification can be extremely difficult and consequently, we made certain simplifications We found that in 30 patients with lesions at level C 3–7, the lesion presented mainly a rotating element, appearing in the radiograph as subluxation and luxation Ten patients had flexion lesions

lower part of the spine, presumably caused by a lesion at this level, which had not previously been diagnosed This could have been the cause of the radicular symptoms

A total of 12 patients, of all those with spinal lesions without medullary deficits, had troublesome complaints daily One patient presented severe complaints because of avulsion of the brachial plexus In this case chordotomy was performed later

In most of the patients the radicular symptoms had been present already during recumbency just after the accident, and had not changed appreciably since In a few patients the condition became worse after discharge In one case anterior fusion was carried out, and transient improvement was achieved

Radiological Follow-up

The overall results of this part of the study are shown in Table 2 Degenerative changes were frequently observed in the radiographs In 19 out of 29 patients with lesions of C3 7 spondylotic changes were found, and in 18 a spontaneous fusion between three or more vertebrae was observed In 15 patients the space between the vertebrae corresponding to the previous level of lesion had diminished No secondary dislocation had occurred since discharge, but the radiographs, which were taken when the patients began mobilization during the primary admission revealed increased angular deformity anteriorly corresponding to the site of the lesion in 6 patients In none of these cases did aggravation of the neurological status occur after mobilization

Table 2 Radiographic follow-up of cervical spine

Level of lesion	C3–7 29 patients	C1–2 19 patients
Disc degeneration	15	2
Spondylosis	19	4
Mobility		
normal	4	11
reduced	6	0
absent	19	3
Instability	0	2

In the patients with spondylosis and/or degeneration of discs, reduced or arrested mobility was observed Only 4 patients with injury

RESULTS

Clinical Follow up

The overall results of this study are shown in Table 1. As regards lesions at level C 3–7, only two patients out of the 29 who reported were completely symptom free at the time of the follow up. In particular patients without medullary lesions reported both radicular symptoms and local complaints. The local complaints advanced by 55 per cent were mainly pain in the neck and shoulders and occipital headaches. Some patients had intermittent pain, while others experienced pain daily. Two patients complained of a sensation of instability. Radicular symptoms were present in 58 per cent. Complaints comprised mainly paraesthesia (15 patients), but also localized changes in sensitivity (6 patients) or slight pareses (7 patients), the last symptom being mainly unilateral.

Table 1. Clinical follow-up in patients with injury to the cervical spine

Level of lesion	C 3–7 29 patients	C 1–2 19 patients
Pain in neck and shoulders	10	6
Occipital headaches	8	2
Sensation of instability	2	1
Local complaints total	16	7
Radicular sequelae		
Paraesthesia	15	3
Sensitivity changes	6	1
Pareses	7	2
Radicular sequelae total	17	3
Medullary sequelae		
Severe	7	0
Slight	4	2
Completely symptom free	2	8

In the group with lesions corresponding to C 1–2 almost half the patients were symptom free, among them most of the children. Local complaints were reported by 7 out of 19 patients or in 37 per cent. Only occasionally were radicular sensations observed with lesions at this level. At the time of the follow up study two of these patients presented recently developed localized spondylotic changes in the

abnormal sliding or deformity Beatson (1963), for example, found that spondylodesis would be indicated in luxations greater than half the body depth, such lesions being unstable On the other hand, laminectomy is not indicated, apart from cases with progressing medullary deficits (Blikra & Ringkjob 1969)

In 212 patients treated conventionally, Cheshire (1969) found only 12 patients with instability at radiographic examination of the cervical spine in flexion and extension at the time of mobilization Increased angle formation was found in 6 of our patients at radiographic examination at the time of mobilization, but none of these patients presented any complaints at this time which might be ascribed to angulation or sliding

During his follow-up study, Rogers (1957) found spontaneous fusion in 8 out of 33 patients

Holdsworth (1963) mentioned that in two thirds of the patients with luxation, spontaneous fusion will develop, which corresponds to our findings

At the C 1 2 level, instability was found in two cases of previous fracture through the odontoid process According to reports in the literature this is rather frequent, and Rogers (1957) described two cases with non union Bohler (1965) also had two cases of non-union among 37 patients with fracture through the odontoid process He did not find that primary spondylodesis was justified, but applied this method in cases of non union

CONCLUSION

Following conservative immobilization in cases of spinal lesions at the level of C 3-7, we have never observed aggravation of medullary deficits

The follow up study showed that the spine had become completely stable in all cases and in more than two thirds of the patients fusion of the affected vertebrae had occurred spontaneously

Healing of fractures of the dens, however, should be carefully checked since the risk of pseudarthrosis is considerable (two out of 11 patients in our series)

The reason for the high frequency of both radicular and local symptoms in injuries at level C 3 7 is not known, but it might be caused both by incomplete reposition at cranial extension and protrusion of discs and, possibly later on, by development of spondylosis

at the level of C 3–7 had normal mobility of the cervical spine None of the patients with lesion at this level presented any signs of instability at the follow up

In lesions at the level of C 1–2, good mobility and no spondylosis were usually found see Table 2 In two patients there was pseudarthrosis between the odontoid process and axis and a maximum sliding of the odontoid process 4 mm anteriorly was observed during flexion In one of the cases this was due to lack of healing of the odontoid process, whereas, on the basis of the radiograph, it must be presumed in the other case that, prior to the injury, a congenital anomaly had been present with fibrous connection between the axis and the odontoid process None of the patients complained of any symptoms which might be caused by the pseudarthrosis A total of 11 patients had fracture of the odontoid

DISCUSSION

It appears from the present series that a considerable proportion of patients without primary medullary lesions will have sequelae for example radicular symptoms and local complaints Even though many of the sequelae recorded were of slight severity only and did not influence the daily life of the patients a total of 12 patients or 34 per cent without medullary sequelae complained of daily or extremely troublesome symptoms

Rogers (1957) found a considerably better prognosis in patients with spinal lesions both in 39 patients treated with posterior fixation and in 38 patients treated exclusively with cranial extension None of his patients who were examined as late as 12 years after the accident presented any local or radiating pains

Janes & Hooshmand (1965) carried out posterior spondylodesis in 32 patients with persistent subjective complaints such as headache pain in the neck and shoulders and paraesthesia None of these patients presented pronounced X ray changes after the spinal lesion In 90 per cent of these cases the complaints disappeared or were alleviated by the operation

Several authors among them Braakman (1970) Durbin (1957) Norton (1962) Raynor & Kingman (1968) and Rogers (1957) attached the greatest importance to surgical treatment of the spinal lesion either in order to change the course of medullary deficits or to stabilize the spine and thereby obtain early mobilization and prevent

Cheshire, D. J. E. (1969) The stability of the cervical spine following the conservative treatment of fractures and fracture-dislocations. *Paraplegia* 7, 193–203.

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Therefore, it would be natural to consider carrying out primary anterior fusion in a greater number of cases.

SUMMARY

1) Out of 71 patients with primary cervical spine lesions admitted over a period of 3½ years, 52 patients were alive 3 to 6 years after the accident. Of these, 48 patients were followed up.
2) The patients were treated mainly with cranial extension and mobilized 4 to 12 weeks after the acicdent, and in no case did fresh symptoms develop. In 6 cases radiographs taken immediately after mobilization revealed increased angulation anteriorly.
3) X-ray examination at the follow-up showed that, in 15 patients out of 29 with lesion at the level of C 3–7, there was degeneration of vertebral discs, and in 19 patients spondylosis had developed. Out of these 19 patients, 18 had definite spontaneous fusion. With a level of lesion at C 2, two cases presented no healing of a fracture through the odontoid process. Out of the 16 patients with a level of lesion at C 2, four had spondylosis between C 2 and C 3.
4) The follow up study revealed stationary local complaints and radicular symptoms in 16 and 17 patients, respectively, out of 29 patients with a level of lesion at C 3–7. Out of 19 patients with a level of lesion at C 2, radicular symptoms were present in 3 and local complaints in 7 patients. Out of the 35 patients without medullary sequelae, a total of 12 complained of daily and embarrassing symptoms.
5) It is concluded that conventional immobilization in lesions of the spine at level C 3–7 will produce good stability of the spine in the long run.
6) It must be considered whether primary anterior fusion would have reduced the frequency of radicular and local symptoms.

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GROWTH IN HEIGHT OF CHILDREN WITH SCOLIOSIS

STIG WILLNER

Accepted 7 iii 73

Treatment of scoliosis still presents considerable orthopaedic problems because our knowledge of the cause and development of the condition is so scanty Even today as many as 80–90 per cent of all cases of structural scoliosis are of the idiopathic type

It is, however, likely that progression of the condition requires the presence not only of the primary causal factor but also of other conditions such as growth and muscular imbalance

It has long been known that growth in height is a *sine qua non* for the development of scoliosis and that most cases of vertebral body change cease to increase at the same time as growth of the spine ceases (Calvo 1957) The deformity also progresses most rapidly during the period of fast growth James (1967) has shown that idiopathic structural scoliosis often makes its first structural appearance within three periods of life, periods during which growth in height is rapid, viz 0–3 years (infantile scoliosis), 5–8 years (juvenile scoliosis) and after 10 years (adolescent scoliosis) The last group is the largest

A search of the literature failed to reveal any more detailed studies of the relationship between growth in children with and without scoliosis Duval-Beaupere (1971) and Duthie (1959, 1971) have studied the relationship between rate of growth and progression of structural scoliosis Duval Beaupere, however, did not notice any evident difference between growth pattern in scoliosis and in a normal population

It was therefore decided to undertake an investigation of this point by comparing growth in height of a group of children with scoliosis,

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non structural as well as structural, and in an age-matched group of children without scoliosis.

MATERIAL AND METHODS

Children with scoliosis

Included in the study were 1,616 children, 905 girls and 711 boys with scoliosis diagnosed over the years 1958–1967. The children were all residents of the city of Linkoping and its environs. The age range was 6 to 19 years at the time of the first examination, 11.8 ± 3.0 (average ± s.d.) and 12.8 ± 2.3 for C-shaped and S shaped cases in girls and 12.2 ± 2.9 and 13.0 ± 3.0 in boys, respectively.

All stages of scoliosis—both of structural and non-structural types—were included, ranging from very mild to occasional, extremely severe cases. All the cases were examined clinically. In standing position a plumb line was suspended from the spinal process of CVII to crena ani. The spinal processes were localized and marked on the skin. Scoliosis was defined as a deviation of 1 cm or more of the vertebral spinous processes from the line between vertebral process of the CVII and crena ani. The severity of scoliosis was measured and expressed in cm of deviation. In addition the child was investigated with regard to whether the deformity was completely corrected in sitting or lying position or by correcting a pelvic obliquity (non-structural scoliosis), or was permanent and withstood attempts at correction (structural scoliosis). A requirement for a case to be rated as structural scoliosis was also the presence of rotational deformity causing thoracic or lumbar deformity, observed with the patient in a forward bending position.

The cases were subdivided into four main types:

Type 1. Left convex C-shaped curvature of the entire spine (66.2 per cent)
Type 2. Right convex C shaped curvature of the entire spine (14.3 per cent)
Type 3. S shaped scoliosis with right convexity proximally (12.6 per cent)
Type 4. S shaped scoliosis with left convexity proximally (6.9 per cent)

The distribution of types of scoliosis among the sexes is demonstrated in Table 1. The severity of scoliosis expressed as maximal deviation in cm is presented in Tables 2 and 3.

Table 1. Distribution of cases among types and sexes (viewed from behind)

Sex	Type of scoliosis			
Boys	496	99	65	51
Girls	574	132	139	60

Table 2 Severity of C shaped scoliosis

Maximal deviation (cm)	*Boys*	*Girls*
1 0	261	325
1 5	267	289
2 0	53	70
2 5	9	14
>2 5	5	8

Table 3 Severity of S shaped scoliosis

Maximal deviation (cm)	*Boys*	*Girls*
1 0	90	139
1 5	13	33
2 0	7	8
2 5	4	12
>2 5	2	7

Roentgenograms were obtained in 598 of the cases The clinical diagnosis of scoliosis according to the above was confirmed in all instances In cases of S shaped scoliosis, type and localization always agreed with the clinical finding In 150 consecutive cases of clinically determined C shaped scoliosis the diagnosis was confirmed except for seven children (4 7 per cent) where an S shaped deformity was found roentgenographically Left right clinical localization always agreed with roentgenological examination The height in standing position was recorded for all the children included in the study and used for the comparison of height between children with and without scoliosis

In the C shaped scoliosis 379 out of 595 boys and 521 out of 706 girls had non structural scoliosis In the S shaped scoliosis 74 out of 116 boys and 161 out of 199 girls had structural scoliosis 917 of the children were measured twice or more and the data of these cases were used for comparison of growth rates between children with and without scoliosis No attempt was made to correct for the decrease in stature caused by the shortening of the trunk due to the scoliosis

The method of clinical investigation provides a sufficiently accurate separation between children with and without scoliosis for the purpose of the present study It does not however provide sufficient accuracy for the classification into more or less severe cases

Control cases

Controls were schoolchildren from the city of Linkoping who were matched with regard to age and year of birth to the children with scoliosis and who had been measured annually between the ages of 7 and 16 All these children came from the school most likely to represent a social cross section of the population of the city The control cases were measured in September each year whereas children with scoliosis were measured at the time of first examination which was randomly spread over the year Children already classified as having scoliosis were excluded from the control group In order to investigate the reliability of the control sample in relation to the population at risk two more schools in the city were included In these children altogether 247 (116 boys and 131 girls) the height had been measured at ages 7, 10 11 and 13 There was full agreement between the controls and this additional sample Moreover data obtained from the population of Sweden (Karlberg et al 1972) and Danish and Norwegian data (Andersen 1968 Skole undersokning av barn i Oslo 1960) were studied for comparison (Figures 1 and 2)

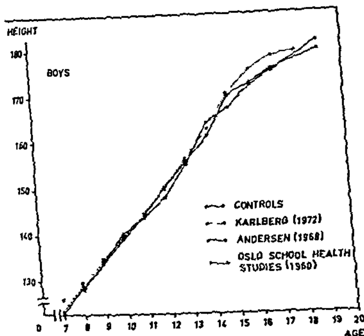


Figure 1 Controls in comparison to contemporary height studies boys

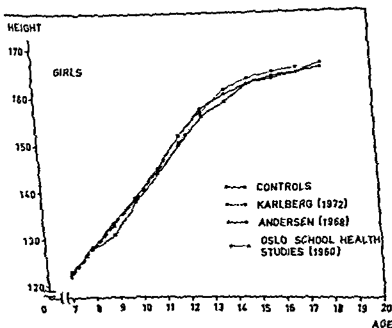


Figure 2 Controls in comparison to contemporary height studies girls

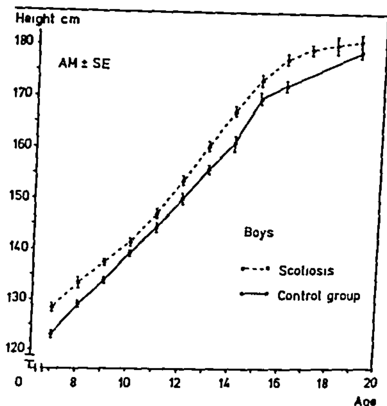


Figure 3. Comparison of height between boys with and without scoliosis

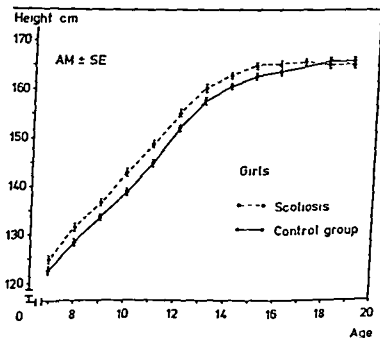


Figure 4. Comparison of height between girls with and without scoliosis.

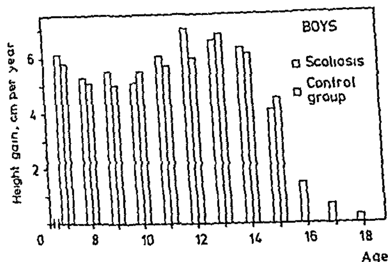


Figure 5 Annual growth in height of boys with and without scoliosis (No controls above 16 available)

In order to permit calculation of the height of adults as well, 150 girls aged 18 and 19 students of theoretical and vocational schools in the city, and 100 military servicemen aged 19 drawn from the same area were included The homogeneity of these data is demonstrated in Figures 1 and 2

Standard statistical methods were applied to the data and differences with a probability level of 95 per cent or better are referred to as significant

RESULTS

Children with scoliosis, non structural as well as structural, were significantly taller than the control children, girls as well as boys, but in girls the difference evened out at the time of cessation of growth, i e at about 15 The same was found in boys, except that the difference was significant even at the age of 16 and possibly later (Figures 3 and 4 Table 4) The growth rates calculated on the longitudinal data are demonstrated in Figures 5 and 6 and in Tables 5 and 6 In boys as well as in girls in the controls there is a decreasing tendency in growth rate during the 8th and 9th years of life However, this decrease does not occur or is at least significantly less pronounced in girls with scoliosis The rapid growth immediately prior to puberty is less pronounced in girls with scoliosis As a result the maximum difference in height between girls with and without scoliosis occurs at about the age of 10 (Figure 7) and after that slowly decreases

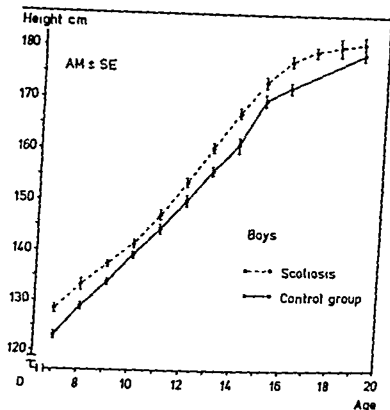


Figure 3 Comparison of height between boys with and without scoliosis

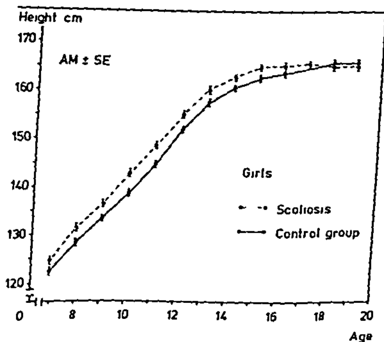


Figure 4 Comparison of height between girls with and without scoliosis

Table 4 Comparison of height between children with and without scoliosis

Age years	Boys						Girls					
	Scoliosis			Controls			Scoliosis			Controls		
	Mean	n	SD	Mean	n	SD	Mean	n	SD	Mean	n	SD
7 (6 5–7.5)	128 4	30	4 4	123 0	124	4 9	124 9	29	5 5	122 5	116	4 9
8 –	133 3	55	5 8	128 8	103	5 5	131 6	76	5 6	128 4	95	5 1
9 –	137 2	64	6 1	133 8	119	5.5	136.8	114	6 3	133 6	100	5.3
10 –	141 4	91	6 7	139 1	121	5 7	143 0	157	7 1	138 9	110	5 5
11 –	147 0	117	7 0	144 2	119	6.3	149 0	197	7 8	145 0	101	5 9
12 –	153 5	125	7 5	150 0	113	6 6	155 2	227	8 1	152 3	102	5 8
–	160 2	157	8 1	155 8	113	6 6	160 4	261	6 7	157 5	103	6 1
–	167 2	173	8 8	161 1	86	7 7	162 6	269	6 1	160 6	100	5 0
–	173 3	173	7.8	169 9	94	7 0	164 9	175	5 2	162 6	55	5 0
–	177 5	108	6 5	172 3	104	5 9	165 0	189	6 0	163 7	98	4 9
–	179 6	73	6 2				165 7	125	6 2			
	180 0	45	10 7				165 0	51	5 8	165 8	98	6 0
	181 3	19	6 3	179 1	98	6 2	165 0	18	5 5	165 7	57	6 1
							164 6	8	6 1			

be noted that already at the time of diagnosis and first examination, the difference in boys with and without scoliosis is considerable

Children with S-shaped, structural scoliosis could not be demonstrated to differ in height from children with non structural C-shaped scoliosis (Tables 7 and 8)

DISCUSSION

It is generally accepted that structural scoliosis can only develop in the growing spine This has been demonstrated by an increased frequency of diagnosis of scoliosis and the progression of the condition in periods of rapid growth and by the fact that structural scoliosis usually becomes stationary after the end of the period of growth However, the difference between the pattern of growth in height of children with and without scoliosis in non-structural as well as structural cases demonstrated here is a novel observation

It must be assumed that growth and height of a given individual are genetically governed At any rate, it is generally accepted that the final height of a given individual is predetermined But it is not known with certainty whether the time and rate of growth are under genetic control According to Tanner (1961, 1962), however, both final body

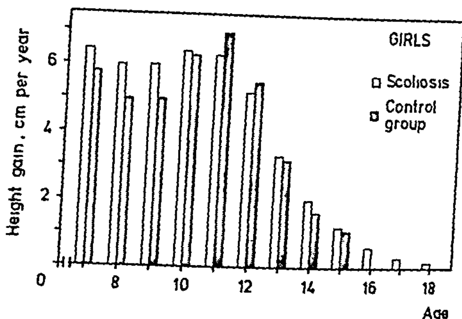


Figure 6 Annual growth in height of girls with and without scoliosis (No controls above 16 available)

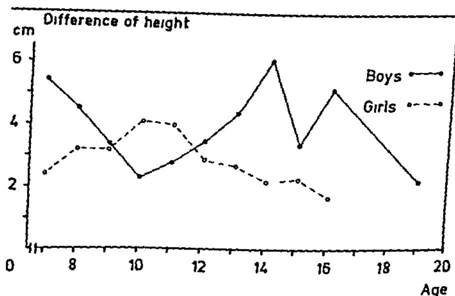


Figure 7 Difference in height between children with and without scoliosis

In boys this pattern is less pronounced There is a tendency towards a more rapid growth before the age of 13 in boys with scoliosis, and this results in a maximum difference between boys with and without scoliosis at about the age of 14 to 16 (Figure 7) It should, however,

Table 7 Comparison of height between boys with functional (C shaped) and structural (S shaped) scoliosis

Age years	Functional C-shaped scoliosis			Structural S shaped scoliosis		
	Mean	n	SD	Mean	n	SD
11	146 9	50	5 4	148 8	4	4 9
12	154 7	44	7 5			
13	160 9	89	9 7	161 5	18	6 9
14	166 2	73	8 0	166 9	12	7 2
15	174 2	77	8 1	172 6	23	7 8
16	1/6 4	46	6 8	176 8	17	6 2

Table 8 Comparison of height between girls with functional (C shaped) and structural (S shaped) scoliosis

Age years	Functional C-shaped scoliosis			Structural S shaped scoliosis		
	Mean	n	SD	Mean	n	SD
10	142 4	81	7 8			
11	149 3	70	7 9	150 0	19	6 1
12	154 9	59	7 3	155 2	12	6 8
13	160 8	114	6 1	160 0	51	7 1
14	163 4	93	6 7	162 5	26	5 5
15	164 7	62	5 8	165 4	34	6 0
16	165 4	42	6 9	164 9	19	6 1

relatively short in childhood but grow more rapidly towards the end of their teens and may continue to grow for a few years after the former group has ceased to grow The final adult height of both groups may then be equal

The genetically predetermined height is however influenced by other conditions such as hormonal disturbances and environmental factors especially socio economic ones

The investigation showed that children with different types of scoliosis both boys and girls above 7 years of age are significantly taller than normals during the growth period but in this material this difference in height of children with scoliosis seems to diminish with increasing age The annual growth in height before the age of 10 of the girls with scoliosis differed significantly from that of their controls

Table 5 Comparison of growth rate between boys with and without scoliosis.

Age years	Growth rate (cm/year)							
	Scoliosis				Controls			
	Mean	n	SD	SE	Mean	n	SD	SE
7	6 1	31	1 2	0 2	5 8	100	1 5	0 2
8	5 3	39	1 7	0 3	5 2	100	1 4	0 1
9	5 5	44	1 8	0 3	5 0	100	1 3	0 1
10	5 1	72	1 5	0 2	5 5	100	1 8	0 2
11	6 1	86	2 2	0 2	5 7	100	1 7	0 2
12	7 0	86	2 8	0 3	6 0	100	1 9	0.2
13	6 6	115	2 3	0 2	6 3	65	2 3	0 3
14	6 3	115	2 7	0 3	6 1	60	2 1	0 3
15	4 1	87	2 4	0 3	4 5	28	2 0	0 4
16	1 6	59	1 6	0 2				
17	0 7	44	0 9	0 1				
18	0 3	24	0 5	0 1				
19	0 1	10	0 3	0 1				

Table 6 Comparison of growth rate between girls with and without scoliosis

Age years	Growth rate (cm/year)							
	Scoliosis				Controls			
	Mean	n	SD	SE	Mean	n	SD	SE
7	6 4	27	1 2	0 2	5 8	98	1 3	0 1
8	6 0	73	1 7	0 2	5 1	100	1 4	0 1
9	6 1	98	1 9	0 2	5 0	100	1 4	0 1
10	6 4	138	2 2	0 2	6 3	100	2 1	0 2
11	6 4	171	2 2	0 2	7 0	100	2 1	0 2
12	5 2	192	2 1	0 3	5 5	100	2 1	0 2
13	3 3	212	2 2	0 2	3 2	95	2 0	0 2
14	2 0	223	1 6	0 1	1 6	70	1 4	0 2
15	1 2	190	1 4	0 1	1 1	47	1 1	0 2
16	0 6	129	0 8	0 1				
17	0 4	65	0 7	0 1				
18	0 2	26	0 5	0 1				

height and the shape of the growth curve are genetically governed but completely or partly independent of one another The growth pattern may vary from one individual to another in a given population (Bayley 1956, Tanner et al 1966) Some attain adult height, body weight and sexual maturity relatively early, whereas others grow slowly, are

Table 7 Comparison of height between boys with functional (C shaped) and structural (S shaped) scoliosis

Age years	Functional C-shaped scoliosis			Structural S shaped scoliosis		
	Mean	n	SD	Mean	n	SD
11	146.9	50	5.4	148.8	4	4.9
12	154.7	44	7.5			
13	160.9	89	9.7	161.5	18	6.9
14	166.2	73	8.0	166.9	12	7.2
15	174.2	77	8.1	172.6	23	7.8
16	176.4	46	6.8	176.8	17	6.2

Table 8 Comparison of height between girls with functional (C shaped) and structural (S shaped) scoliosis

Age years	Functional C-shaped scoliosis			Structural S shaped scoliosis		
	Mean	n	SD	Mean	n	SD
10	142.4	81	7.8			
11	149.3	70	7.9	150.0	19	6.1
12	154.9	59	7.3	155.2	12	6.8
13	160.8	114	6.1	160.0	51	7.1
14	163.4	93	6.7	162.5	26	5.5
15	164.7	62	5.8	165.4	34	6.0
16	165.4	42	6.9	164.9	19	6.1

relatively short in childhood but grow more rapidly towards the end of their teens and may continue to grow for a few years after the former group has ceased to grow. The final adult height of both groups may then be equal.

The genetically predetermined height is, however, influenced by other conditions such as hormonal disturbances and environmental factors especially socio-economic ones.

The investigation showed that children with different types of scoliosis both boys and girls, above 7 years of age are significantly taller than normals during the growth period, but in this material this difference in height of children with scoliosis seems to diminish with increasing age. The annual growth in height before the age of 10 of the girls with scoliosis differed significantly from that of their controls

The girls with scoliosis grew faster than their controls up to this age but slower afterwards During the first few years after puberty the rate of growth was roughly the same for both groups, but then seemed to decrease earlier in the girls with scoliosis than in the controls

In the boys the difference in annual growth was not so clear The tendency, however, pointed towards a slower growth in the controls up to 12 years of age, though the difference was not statistically significant Yet here, too, the boys with scoliosis were taller than their controls

The scoliotic children of both sexes ceased to grow earlier than their controls As this material was not corrected for the shortening of the trunk due to the scoliosis there might be a possibility that a progression of the scoliosis has negatively influenced the measured height

This suggests that children growing quickly are more exposed to the risk of the condition than those growing more slowly One might very well imagine that rapid growth might interfere with the posture of the trunk, which together with other factors predisposing to scoliosis, may result in a disorder of the growth of the spine and a consequent development of a structural scoliosis What argues against this growth pattern having anything to do with the primary cause of scoliosis or being one sign and scoliosis another of a clinical entity is that all types of scoliosis both non structural and structural of the series showed a uniform growth pattern and that all differed significantly in this respect from the controls The number of severe cases was however too small to demonstrate with certainty any difference between types of scoliosis

Figure 7 gives the difference in height between the controls and the scoliotic boys and girls At first sight the two curves seem to go in opposite directions but on closer analysis it will be realized that both curves may perhaps be similar but with a phase lag the boys showing a similar tendency but 2 3 years later which also is roughly the interval between puberty in boys and girls

The declining part of the curve for 7 to 10 year old boys may correspond to what one might expect in girls before 7 8 years of age But this is only an assumption because the number of girls below 7 years was too small to allow any conclusion On the other hand the difference in growth between children with and without scoliosis was increased during puberty for both sexes and afterwards decreased up to adult age

Figure 7 also demonstrates that the difference between the height of

scoliotic children and their controls varied considerably This argues for the generally accepted assumption of a correlation between the period of rapid growth and the onset of or, at any rate, progression of scoliosis Furthermore, these observations suggest that those children who grow quickly earlier in life than average are more inclined to develop scoliosis under otherwise equal conditions

SUMMARY

Growth in height between the ages of 7 and 19 in individuals with scoliosis, both non structural and structural, and living in Linkoping or its environments was compared with that of sex- and age matched controls The loss in body height due to scoliosis *per se* was ignored The true difference of growth in height was therefore greater than that recorded The controls agreed in height with three other height measuring studies in Scandinavia

Between the ages of 7 and 15 years the boys and the girls with scoliosis were taller than their controls Growth in height seemed to cease 1 2 years earlier in the patients than in the controls In adult age both groups seemed to be equally tall Between the ages of 7 and 9 the patients with scoliosis grew faster than their controls This suggests that the prepuberal growth phase occurs earlier in children with scoliosis

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POST-PNEUMONECTOMY SCOLIOSIS

Stig Jacobsen, Arne Rosenklint & Erik Halkier

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Thoracogenic scoliosis may be caused by changes in the thoracic wall proper or in the pleural cavity.

Orthopaedic surgeons have mainly focussed their interest on post-thoracoplasty scoliosis, whereas investigations of the spinal changes following pneumonectomy are curiously enough few in number (Groot 1971). This is presumably due to the fact that post-surgical examinations have centred primarily on the possible recurrence of the cancer, whereas the severe physiological and anatomical disturbances as a result of the pneumonectomy have been considered comparatively unimportant.

The object of the present study was to examine the degree and the frequency of one of the many post-surgical consequences of shrinkage etc. in the pneumonectomy cavity, viz. scoliosis of the thoracic spine.

MATERIAL AND METHODS

Thirty-four patients who had undergone pneumonectomy 2–8 years previously were examined. At the time of operation the patients were from 16 to 71 years old, with an average age of 5[illegible] years. There were 28 men and six women. One patient could not be examined because of severe lung insufficiency. The material thus comprises 33 patients.

Each patient was questioned about back troubles and was examined clinically and radiologically. Three X-ray photos were taken of the spine on a 90 × 30 cm film: one standing and two sitting with right and left ischial tubercles elevated respectively. The maximum amount of scoliosis is indicated by its summit = apex, and its extent by the top and bottom vertebrae of the scoliosis.

The degree of the scoliosis was evaluated by measuring the angle of the curve a.m. Cobb (1948). The rotation of the scoliosis was likewise evaluated a.m. Cobb (1948) graded 0, +, ++, +++ depending upon the rotation of the spinous process from the centre line (Table 1).

Operative procedures

Twenty patients underwent a left sided pneumonectomy and 14 a right sided pneumonectomy. The operation was carried out through the 5th or 6th intercostal space without costal resection. With this entry the costo transverse ligaments are often divided. After the operation the pleural cavity spontaneously fills itself during the first post-operative days with adjustment of possible pressure increase to avoid dislocation of the mediastinum.

Two patients had post operative empyema, and one of these was later subjected to thoracoplasty.

RESULTS

Subjective complaints

Only three patients complained about pains in the muscles of the back. Five patients complained about pains in the shoulder spreading to the arm. Three patients, one man and two women, felt cosmetically inconvenienced by the development of scoliosis.

Only complaints attributable to the spine are reported here.

Objective findings

On ordinary clinical examination, 31 patients showed a mild to moderate degree of scoliosis. None had more severe scoliosis. The scoliosis was convex towards the unoperated side, except in two patients, in whom the curve was directed to the side operated. The shoulder had sunk by 1–4 cm on the side of the pneumonectomy in 26 patients. Nine patients had a slight rotation towards the side of the pneumonectomy on bending forward.

Radiological findings

Twenty-three patients had a scoliosis of a mild degree (5° to 20°) (Table 1). In 21 it was fixed. Usually it extended only 4 to 5 vertebrae. All of the patients had mobile compensatory secondary curves below and above the major curve. Twenty one patients showed no rotation, whereas 10 patients demonstrated a rotation of degree + +.

No changes (congenital anomalies, metastases) were observed which could explain the development of the scoliosis, and no scoliosis was noted on the pre operative chest X-ray. The significance of this must be taken with a certain reservation, as milder cases of scoliosis can escape notice on these films.

Three patients are not included in the tables. One patient with left-sided pneumonectomy had an S-shaped scoliosis, dextro-convex, of the

thoracic vertebrae 5–10 It was not possible to establish which of the curves was the primary one Two patients showed a scoliosis which was convex towards the operated side One of them had had a post-operative empyema and later underwent thoracoplasty This patient had an angle of scoliosis of 5° The other one underwent a left-sided pneumonectomy and developed a sinistro convex scoliosis of 17° It was not possible to find any explanation of this extraordinary observation

Table 1 Distribution of patients according to severity of the thoracogenic scoliosis

Number of patients	Angle of scoliosis
7	0°– 5°
9	5°–10°
10	10° 15°
4	15° 20°
Total 30	

Table 2 Distribution of patients according to apex of angle of scoliosis

Number of patients	Apex of angle of scoliosis
2	C 7
0	Th 1
4	Th 2
5	Th 3
13	Th 4
4	Th 5
2	Th 6 and further down

DISCUSSION

Bisgard (1934) described two different types of scoliosis, those which develop in the thoracic wall proper and those which develop from changes in the thoracic cavity the so-called pleural scoliosis

The most studied scoliosis in the first group is the thoracoplastic type where the convexity is directed towards the operated side and which has a rotation directed towards the concavity (Dwork et al 1951, James 1967 Loynes 1972 Stauffer & Mankin 1966) Bisgard in 1935 produced scoliosis in animals by thoracoplasty and Langenskiold & Michelsson (1962) brought about progressive scoliosis in animals by

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single previous investigation seems to have dealt with the occurrence of scoliosis following pneumonectomy (Groot 1971)

It is impossible to judge from the post operative films how quickly the scoliosis develops and for how long it progresses In the thoracoplasty scoliosis, it seems to appear a few days after the operation and to progress over several years (Bisgard 1934, Loynes 1972)

All of the scolioses examined by us are of the mildest degree according to the Scoliosis Research Society's classification (0°–20°) (Keim 1972)

Because of the slight difference in age of the patients nothing can be said about the influence of age on the scoliosis In an examination of 67 pneumonectomy children under 18 years of age Groot (1971) found no scoliosis in 30 per cent Forty per cent had an angle of scoliosis of less than 15° Eighteen per cent had an angle of scoliosis between 15° and 30°, and 12 per cent had an angle of scoliosis of more than 30° In children developing scoliosis the angle seems to be a little larger than the angle shown in our adult cases In the thoracoplasty patients there does not seem to be any connection between age and degree of scoliosis (Dwork et al 1951, Loynes 1972)

Our patient who had undergone thoracoplasty after pneumonectomy did not develop a pleural scoliosis, but a thoracoplasty scoliosis of 5° Bisgard (1934) cites examples where pleural scoliosis can be corrected or possibly over corrected by thoracoplasty

In conclusion it may be said that pneumonectomy patients almost inevitably develop scoliosis high up in the thoracic spine with the convexity towards the unoperated side The scoliosis appears as a link in the shrinking processes following a pneumonectomy From a functional point of view the scoliosis does not seem to have caused problems for the patient

SUMMARY

Thirty four post pneumonectomy patients have been examined from 2 to 8 years after operation Ninety per cent of the patients showed a mild scoliosis high up in the thoracic spine with the convexity towards the unoperated side and with slight or no rotation

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Figure 1 Typical X ray of a patient who had undergone pneumonectomy on the left side Severe changes as a result of shrinkage of the pneumonectomy cavity can be clearly seen The angle of the scoliosis is superimposed

removing the posterior part of some ribs They stressed the significance of the costotransverse ligaments as important for the development of this type of scoliosis

Pleural scoliosis is caused by the post-operative intrathoracic changes After a pneumonectomy the cavity is filled with blood and exudate This becomes connective tissue which subsequently shrinks and exerts traction on the surrounding organs and spine The resulting scoliosis away from, and a mild rotation toward the operated side can be explained by the fact that the pulling forces mostly affect the weakest part of the thoracic spine Thus the spine will curve over the operated hemithorax

This is, however, not in accordance with Bisgard (1935) who thought that the effect on the spine is produced through the ribs which approximate laterally due to the pulling forces This transfers a pressure on the spine to which the ribs are fixed

The incidence of scoliosis in normal people over 50 years of age is 6 per cent (Vanderpool et al 1969) All our post pneumonectomy patients had scoliosis which must be ascribed to the operation Only a

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SECONDARY DYSPLASIA AND OSTEOARTHROSIS OF THE HIP JOINT IN FUNCTIONAL AND IN FIXED OBLIQUITY OF THE PELVIS

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Accepted 18 ix 74

A difference in leg length usually leads to tilting of the pelvis and to a compensatory bowing of the lumbar spine. The alteration of spine biomechanics may cause low backache (Rush & Steiner 1946, Nichols 1960) and may even be of significance in the development of degenerative changes in the spine (Morscher 1972). However, different opinions on this subject do exist: thus, Hult (1954) found no correlation between symptoms from the lumbar spine and pelvic tilt. Also the knee joint of the longer limb may be exposed to early and severe damage in leg length disparity (Dixon & Campbell Smith 1969).

The purpose of the present paper is to present some cases with secondary changes in the hip joint on the side of the longer leg in long-lasting functional as well as in fixed pelvic obliquity.

CASE REPORTS

Case 1 (Figure 1 a–d). Woman born in 1925. She had osteomyelitis in the left hip and knee at 10 years of age. When first seen in our clinic in 1960, 35 years old, a pelvic tilt and a compensatory bowing of the spine was present (1 a). The left hip was anchylotic in 23° of abduction (1 b), but the right hip was normal with an anatomical CE angle of 30°. Functionally, however, the angle was only 10°. A corrective osteotomy was recommended, but the patient refused. 10 years later (1 c) a marked subluxation and osteoarthrosis had developed in the right hip. Osteotomies were now accepted in both hips (1 d).

Case 2 (Figure 2 a–e). Woman born in 1930. She had multiple enchondroma, and a considerable difference in leg length developed in childhood. X ray at 12 years of age (2 a) shows the functional adduction position in the right hip and a CE angle of 2° (anatomically 20°). She continued to walk without correction of the leg length disparity, which at the age of 24 years was 17 cm. X ray then showed a definite acetabular dysplasia and incipient coxarthrosis (2 b). She was given a

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1a



leg prosthesis which was used very little during subsequent years The degenerative disorder increased (2 c–d) and later an adequate correction of the length disparity was accepted (2 e)







Case 3 (Figure 3 a–d). Boy born in 1954. At the age of 2 years a 3 cm shortening of the right leg was found owing to a hypoplasia of the femur (3 a). Movements and x-rays of the hips were normal. At the age of 8 years the difference in leg length was 4 cm and the hips were still normal (3 b). At 13 years of age the right limb was 6 cm shorter than the left. He had used an insufficient correction and x-ray showed dysplasia of the acetabulum (3 c). Epiphysiodesis of the left femur was performed. At the age of 16 years dysplasia and subluxation of the hip was present (3 d) and a varus osteotomy was done.


2 c L


2 d


2 e





metrical hip function started at various ages from early infancy up to 10 years In some of the cases early x rays are not available, but none of the cases are suspected of having a primary disorder of the hip in question

The present material clearly shows that secondary changes may develop in the hip of the longer leg i e in the hip held in adduction



Case 4 (Figure 4 a–b) Girl born in 1958 She had a hypertrophy of the left limb owing to a vascular malformation (Klippel-Trenaunay syndrome) At the age of 4 years the difference in leg length was 2 cm, and the hips were normal (4 a) Ten years later the left leg was found to be 3 5 cm longer than the right She had used an insufficient correction for the length difference, and x ray showed definite dysplasia and subluxation of the left hip (4 b) An osteotomy was now performed

Case 5 (Figure 5) Boy born in 1962 with a congenital bowing of the right tibia At the age of 3 years neurofibromatosis Recklinghausen was also diagnosed, and at eight a structural scoliosis of the thoracic spine was observed At the age of one year the right tibia was operated upon because of pseudarthrosis, but union failed During the following years he walked with a splint without sufficient correction of the leg length inequality which at 11 years was found to be 8 5 cm X ray showed dysplasia and subluxation of the left hip

Case 6 (Figure 6) Woman aged 21 years In early infancy she had a fever illness supposed to be poliomyelitis of moderate degree At examination a 2 cm tilt (to the right) of the pelvis was found Hip movements were unrestricted but a slight paresis of the abductor muscles was found in the right hip and also of the anterior tibial muscles She had no paresis of the left leg X ray showed slight dysplasia in the left hip, CE angle 18° (functional 15°) as compared to 26° in the opposite hip

Case 7 (Figure 7) Boy born in 1958 A leg length disparity of 2 cm was found in 1969 at a routine examination of school children Two years later the difference in leg length was 2 5 cm He had no symptoms or any disturbed function X ray showed pelvic tilt and a slight dysplasia of the right hip with an anatomical CE angle of 15° as compared to 21° in the left hip

DISCUSSION

Seven cases with pelvic tilt are recorded Six had leg-length disparity of varying degrees, from two to seventeen cm, and one had a fixed pelvic obliquity after ankylosis of one hip in abduction The asym-





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Seven cases with pelvic tilt are recorded Six had leg-length disparity of varying degrees, from two to seventeen cm, and one had a fixed pelvic obliquity after ankylosis of one hip in abduction The asym-

during the growing age The changes, acetabular dysplasia, subluxation, and subsequent osteoarthrosis are similar to those which are seen in congenital dysplasia of the hip joint

Tilting of the pelvis leads to an adduction of the hip joint and to a decreased acetabular covering of the femoral head on the side of the longer leg The functional CE angle is reduced in the adducted hip, the loaded area will decrease, and the stress per square cm will increase owing to the tilting The correlation between limb shortening, CE angle and loaded area was calculated by Krakovits (1967) who found that a leg length disparity of, for instance, 4 cm leads to a decrease in the CE angle of about 9° and to a decrease in the loaded area of about 4 square cm when the distance between the centres of the femoral heads is 2a cm Furthermore, Merchant (1965) showed that the abductor muscle force is greatest with the pelvis in adduction Consequently the adducted hip is exposed to a considerably increased stress In addition, the direction of the resultant force in the hip joint is displaced towards the outer part of the acetabulum

The stato-dynamic changes mentioned are most probably the reasons or the remodelling of the acetabulum, the subluxation and the osteorthrosis of the hip joints in some of the cases presented Gofton 1970) is of the opinion that leg length inequality may be a major contributing factor in the development of unilateral osteoarthrosis of he hip

Experiments in growing animals have shown that maintaining of the hind limb in inward rotation or extension for a few weeks leads to remodelling of the hip joint and even dislocation (Wilkinson 1962, Sijbrandij 1963 Salter 1966) Also immobilization of the knee joint in extension leads to dislocation of the hip joint in growing rabbits when the hamstring muscles are intact (Michelsson & Langenskiold 1972)

The present clinical observations as well as the experiments in animals support the opinion that postnatal environmental factors acting in the first few months of life during rapid growth may be of significance in the development of congenital dysplasia of the hip joint (Ulfeld 1962 Ryder et al 1962 Bjerkreim 1974)

To prevent subluxation and degenerative changes in the hip joint it seems important to level the pelvis in patients with leg length inequality







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FRACTURES IN CHILDREN WITH MYELOMENINGOCELE

Report of 15 Cases and a Review of the Literature

A NAVARRO QUILIS

Accepted 21 v 74

In recent years orthopaedic surgeons have seen increasing numbers of children with paralysed lower limbs due to spinal dysraphism The problem is not new, but the advances of neurosurgery and urology have given a much better prospect of life to these children Therefore, the correction of the limb deformities is a challenge that has to be accepted in order to help them to stand and walk

However parallel with the better general outlook and the improved management of the lower limb deformities in these children, an increasing number of fractures has occurred and some of the fractures show an unusual pattern of repair

This paper reports a study of 130 children with myelomeningocele, fifteen of whom sustained fifty-five fractures

REVIEW OF THE LITERATURE

Gillies & Hartung (1938) were the first to describe undisplaced fractures of the upper metaphysis of the tibia in children with myelomeningocele The fractures in the two cases they described healed with excessive callus formation each involved some diagnostic difficulty demanding in one case bone biopsy to exclude sarcoma and, in the other blood investigations to exclude syphilis

Alhaume (1950) reported two cases with myelomeningocele of the lumbosacral region In both cases there were diaphyseal fractures of the femora the second case showed excessive callus formation

Katz (1953) described a patient with myelomeningocele who sustained four fractures of the same leg, there was no apparent trauma

SUMMARY

Seven cases showing secondary changes of the adducted hip in pelvic tilt have been reported The affection varies from slight dysplasia to severe subluxation and arthrosis of the hip Adjustment of the existing leg-length inequality is recommended.

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However, parallel with the better general outlook and the improved management of the lower limb deformities in these children an increasing number of fractures has occurred and some of the fractures show an unusual pattern of repair.

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Katz (1953) described a patient with myelomeningocele who sustained four fractures of the same leg; there was no apparent trauma

and they healed with "excellent callus formation" He stated spontaneous fractures do not occur in the paralysed lower limb children who have previously suffered from poliomyelitis

Jeannopoulos (1954) described bone changes in six children lower limb mono- or paraplegia He postulated the existence of tro nerves to bone, seeking support in the histological findings of de Ca (1925) and Hurrell (1938) each of whom had shown nerve fibre close contact with osteoblasts

Carr (1956) found among 100 cases of spina bifida four that sustained fractures Two of these formed excessive callus, and sustained so many fractures that the limb was eventually amputat Histologic examination of the callus from the last case did not sh the characteristic "chondroid tissue", which Fairbank & Baker (19 observed in the hyperplastic callus of osteogenesis imperfecta

Golding (1960) showed and commented on the radiological appe ances of two cases with involvement of the metaphyseal region of t knee and of the distal tibial metaphysis The changes regressed wi conservative treatment and the lesions 'may resemble sarcomata Charcot's arthropathy"

In the same year Exner reported two examples of excessive calcific tion in limbs of a patient with myelodysplasia, perhaps due to spontan ous fractures (Exner 1960) Oehme (1961) described two cases wi metaphyseal changes and a periosteal reaction similar to the lesions c scurvy, but the ascorbic acid excreted in the urine in the 24 hour hours after a massive dose was normal

Soutter (1962) described lesions of the metaphyseal and epiphysea regions of the knee and ankle, and pointed out the diagnostic dif ficulties with osteomyelitis and bone sarcoma

Komprda (1964) described a case with thickened sclerosed and fragmented new bone formation

Thompson et al (1964) reported three children, out of twenty-two with myelomeningocele, with fractures of the lower femoral metaphysis, and one with a fracture-separation of the lower femoral epiphysis All presented excessive callus formation He pointed out that cases of this type could be confused with the battered child syndrome"

Gyepes et al (1965) described seven children with changes in the metaphysio-epiphyseal region of the lower femora and tibiae

Robin (1965) described four cases that sustained fractures of the lower limbs at different levels He pointed out that not all were spontaneous fractures

PATIENTS

In the last fifteen years 130 patients with myelomeningocele, suffering from partial or total paralysis of the lower limbs have received orthopaedic treatment in this and the associated hospital Among these patients there are 15 who sustained a total of 55 fractures Only one was born before 1960

The degree of callus formation was assessed by comparing with normal children and grouping the results as more equal or less

Clinical details of the patients sustaining fractures

Incidence The percentage of children with myelomeningocele sustaining fractures is approximately 11·5 This is clearly higher than in normal children of the same age group The number of fractures that occurred in each child is seen in Table 1

Age Twenty six per cent of the fractures occurred in the 4 to 5 year old group and 20 per cent in the 2 to 3 year old group

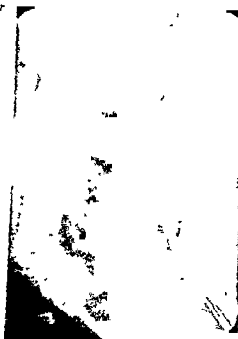
Table 1

No of fractures	No of children
1	3
2	3
3	4
4	1
5	1
6	1
7	1
12	1



Figure 1 Fracture separation of the left lower femoral epiphysis with large periosteal reaction Lateral view

Figure 2. Showing the large amount of callus formation and the patchy, irregular appearance ("lumpy or woolly") together with the extensive periosteal reaction. No comment is made on the suspicious appearance of the upper tibial metaphysis.



Bone fractured Sixty two per cent of the fractures occurred near the knee joint, an uncommon site for fracture in normal children (Blount 1955) The greatest number of fractures occurred at the junction of the middle and lower third (24 per cent)

Callus formation Nineteen of the fractures healed with a large amount of callus formation (Figure 1), 23 with a moderate amount and 10 with a minimal amount In some instances (Figure 2) the callus had an irregular radiographic appearance giving a "lumpy" or "woolly" picture Similar changes were observed by Gillies & Hartung (1938) in the form of lack of trabeculation

Level of paralysis Fifty-one per cent of the fractures occurred in children paralysed below L 2—L 3 levels It is noticeable also that 16 out of the 19 fractures that healed with excessive callus formation belonged to this group

Causes of the fractures The causes of the fractures are shown in Table 2

Table 2 Relationship of the skeletal findings to injury, surgical intervention, plaster immobilization and passive mobilization

Fractures caused by passive mobilization or manipulation of stiff joints	8	30
Fractures caused in theatre (operation, plaster wedging, etc)	10	
Fractures occurring after removal of plaster casts	12	
Fractures due to a fall	4	
Fractures occurring when walking or in bed without apparent cause	16	21
Fractures without known cause	5	

It can be seen from the table that 30 fractures (55 per cent) have an association with treatment received in the way of physiotherapy, surgical intervention, and plaster immobilization. 21 fractures (38 per cent) occurred without any apparent reason ("spontaneously"). Occasionally it has been reported by the nursing staff that the legs of these patients have been trapped between the side bars of the cot.

Fracture separation of the epiphysis. This lesion occurred in three cases (Figures 2 and 3). In one there was radiological evidence of closure of the epiphyseal cartilage (Figure 4).

Unusual presentation. In two cases the presenting symptoms of the fracture were raised temperature and malaise. In one an operation was performed to exclude osteomyelitis.

Vitamin C excretion

Vitamin C saturation tests were performed in seven of the patients studied and in three other children being treated for other conditions.

Test procedure. Three hours after a meal 15 mg per kg/body weight of vitamin C is administered orally. The urine passed in the first four hours is discarded and the urine passed during the next two hours is collected in a bottle with 10 ml of glacial acetic acid. Quantities of vitamin C lower than 15 mg are considered abnormal.

Great difficulty was experienced in collecting some of the specimens from the children with myelomeningocele due to incontinence and leakage of the collecting bags.

Table 3

	Case No	Amount of vitamin C excreted
Myelomeningocele patients	2	< 1 mg
	3	2.5 mg
	4	1.5 mg 5.6 mg
	6	< 1 mg
	8	< 1 mg
	10	< 1 mg
	13	18.5 mg 3.8 mg
Other patients	1	< 1 mg
	2	4.2 mg
	3	7.1 mg

1) Boy 3 years old. Mongoloid. Fracture of the right femur four weeks prior to test.
2) Girl four years old. Fracture of the left femur three weeks prior to test.
3) Boy three years old. Congenital talipes equinovarus surgical correction of the foot one week prior to test.

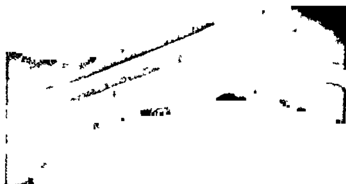


Figure 3 Shows a fracture of the lower femoral metaphysis and a fracture separation of the upper tibial epiphysis

Four of the myelomeningocele patients with low vitamin C excretion had their wrists examined radiographically but showed no signs of ascorbic changes

DISCUSSION

Surely the most striking thing is the high incidence of fractures The fact that 38 per cent occurred spontaneously and 55 per cent occurred in association with treatment received indicates that there is a strong predisposition to sustain fractures

The cause of the fractures

Neither the number nor the type of fractures is peculiar to children with myelomeningocele, it also occurs in children with paraplegia from other causes such as subdural haematoma (Caffey 1946), fractures of spine (Katz 1953, Robin 1965), avulsion of lumbosacral roots, transverse myelitis (Jeannopoulos 1954), and tumours of the cord (Robin 1965) However, in children with atrophic limbs due to poliomyelitis, in which sensation is intact, spontaneous fractures are rarely found (Katz 1953, Jeannopoulos 1954)

Absence of active movements in the limbs, due to paralysis, produces bone atrophy*, and the prevention of passive movements caused by brace treatment, enhances it still further This could explain the 55 per cent of "per-therapeutic' fractures that occurred in the patients under study However, fractures occur in atrophic bone much more



Figure 4 *Multiple fractures Right and left shafts of femora and right lower femoral metaphysis Notice left femoral epiphyseal line is closed*

frequently when it is deprived of sensation This may be because strains applied to the legs are not checked by these patients with absence of normal sensation

In conclusion then, the predisposition to fractures in these children seems to be due

a) to atrophy of the bones of the lower limbs, or
b) to sensory deprivation of the limbs

The cause of bone atrophy

Is the atrophy of the bones of the lower limbs of these children due to disuse i e to lack of stimuli provided by weightbearing and by muscle action or alternatively are 'trophic impulses" necessary for proper bone growth and maintenance?

Each of these possibilities will be discussed in turn

1) *Disuse bone atrophy* Nothing is known of the precise nature of the bone atrophy in these children, but in experimentally denervated limbs it has been found that the cause of the tissue atrophy is an

* We have adopted the terminology used by McLean & Urist (1961) 'In our opinion atrophy is the term that most nearly describes the condition characterized by deficient formation of new matrix and we have used this as a general designation"

"The use of the term osteoporosis usually refers to a systemic condition in contrast to the local atrophy of disuse"

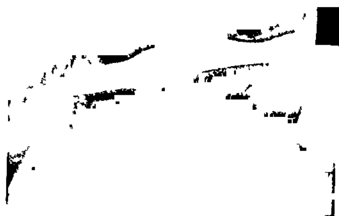


Figure 5 Lateral view of Figure 4 showing the fracture of the upper tibial metaphysis

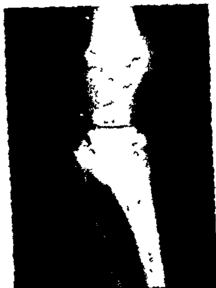
increase in the rate of resorption in the presence of normal or subnormal formation, both in bone (Landry & Fleisch 1964) and in muscle and bone (Slack 1954) Geiser & Trueta (1958) arrived at the same conclusions in bone atrophy caused by section of the tendo calcaneus in the rabbit

Heaney (1962) studying the bone atrophy of patients who suffered from poliomyelitis also stressed the increased bone resorption and bone formation in the early stages and the lower turnover at later stages when the bone atrophy did not increase Jowsey et al (1965) studying "senile osteoporosis" reached the same conclusion All these views are opposed to the classical belief that bone atrophy is caused by diminished bone formation only (Albright & Reifenstein 1948)

In disuse atrophy an increased excretion of calcium has been reported This gives the patients a calcium balance on the negative side (McLean & Urist 1961, Rose 1966)

2) *"Trophic bone atrophy"* The view that bone maintenance could be due to trophic impulses to the osteoblasts has had its adherents (deCastro 1930, Hurrell 1938, Jeannopoulos 1954) But Eloesser (1917) did not find any morphological changes in the ribs of cats deprived of their posterior root innervation He reported no physico-chemical changes in deafferented limb bones, although the joints of such cats showed traumatic changes resembling arthritis Corbin & Hinsey (1939) found that cats whose hind limb had been deafferented and sympathectomized for as long as three years developed neither macroscopic nor microscopic changes in their bones If the animals were kept

Figure 6 Two months after a fracture of the upper tibial metaphysis Continued walking Notice the irregular callus formation



in small cages, no joint changes were observed, but if their mobility was unrestricted they developed arthritis of the hip joint Corbin & Hinsey concluded, therefore, that bones and joints are not supplied with nerves with a specific trophic function "Deafferentation results in a loss of the protection afforded by the proprioceptive mechanism and, therefore, may lead to attrition arthritides in those joints subjected to constant trauma"

Gillespie (1954) denervated kittens' limbs and concluded that the bone changes in weight and strength which follow paralysis are due to the secondary loss of muscular activity No evidence could be obtained that nerves exert any specific trophic influence on bone This view has been supported by Ring (1961), and by Kharmosh & Saville (1965)

The pattern of healing

The amount of callus formed round the fractures in the present study has been shown to be very variable, some cases formed a minimal amount of callus while others showed exuberant callus formation (Figures 1, 4 and 5) In normal children callus formation is sometimes very marked (Aegerter & Kirkpatrick 1963)

The reason why a third of the fractures in these children show exuberant callus is unknown, but it may be an expression of a high

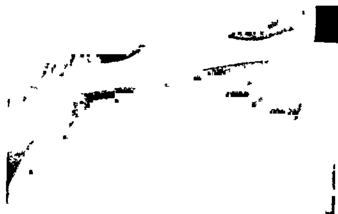


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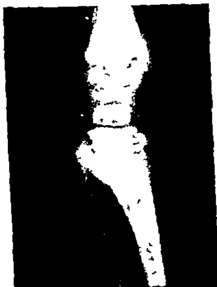
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Figure 7 The same as above oblique view

level of "metabolic flux" in the bone at the time of the fracture or it may be that such fractures are difficult to immobilize due to the lack of sensation

The exuberant callus formation of some of the fractures described in the present work is not peculiar to paraplegic children, it has also been reported in patients with osteogenesis imperfecta (Fairbank & Baker 1948, Strach 1953, Schwarz 1961) But in osteogenesis imperfecta the maximum amount of callus occurs two to six months after the fracture In contrast, the maximum amount of callus formed in fractures in children with myelomeningocele is reached within a few weeks Some of the cases of osteogenesis imperfecta with exuberant callus formation are accompanied by pyrexia as in two of the present cases

The metaphyseo-epiphyseal lesions (Figures 6 and 7) have the radiographic appearance of a neurotrophic joint (Brailsford 1948) Eichenholtz (1966) reports that the changes present in paraplegic joints are not of the same nature as Charcot's joints

Regarding the type of callus in these fractures, Eichenholtz (1963) says "It seems never to progress to mature compact bone, but instead seems to hover in limbo between the coarse fibrous bone of recent osteoid deposition and adult cortical bone" I cannot support this statement because microscopically the callus removed from one of the cases has a normal appearance

1965, Reyes Cunningham et al 1971) Our own experimental ... shows that the hyperplastic callus depends on the mobility of the fracture, the type of bone involved and the period of bone atrophy (Navarro & Peiró 1974, Navarro et al in preparation)

Does hypovitaminosis C contribute?

The possibility exists that the exuberant callus is an expression of a subclinical deficiency of vitamin C, in view of the low excretion of this vitamin in seven of the patients studied Against this are the following facts

a) In some cases of exuberant callus in children with myelomeningocele, normal levels of vitamin C have been found in blood and urine (Oehme 1961, Thompson et al 1964)
b) Not all the fractures in the seven children studied healed with excessive callus formation
c) Three other children who underwent the test also showed low excretion (see Table 3)

Experimentally it has been shown that fracture healing in vitamin C deficient animals is low and accompanied by severely altered callus formation (Strauch & Geifer 1963) In chronic scurvy the osteoblastic activity is markedly suppressed (Banks 1943, Silvermann 1953)

Two further facts suggest that the exuberant callus of these fractures is not due to a deficiency of vitamin C, viz

a) The rapidity of union of the fractures in these children in contrast to the slow union of fractures in scurvy, and
b) There is no radiological evidence of scurvy in the metaphyseo epiphyseal areas

Suggestions for prophylaxis

It seems very likely that insensitive limbs are easy to strain and damage between the side bars of the cots used in children's wards in this country It would be better to use transparent plastic planks for the sides of the cots for these children As an additional aid to prophylaxis it has been suggested that the strength of the bones in these children might be greater if splints were used instead of plaster (Strach 1967)

Figure 8 Shows extensive new bone formation around the operated hips, but especially surrounding the right femoral shaft, the epiphysis is slightly displaced and all the callus seems to come from the physeal region On the left knee the metaphysis shows some sclerosis and fragmentation but without callus formation



CONCLUSIONS

1) Among 130 cases of children with myelomeningocele, 15 sustained 55 fractures
2) More than half (55 per cent) of the fractures occurred per-therapeutically having a clear association with manipulation and immobilization in plaster, which leads to further rarefaction
3) Sixty per cent of the fractures occurred "spontaneously", in most cases the patients were in bed and their legs being trapped in the side-bars of the cot was suspected as the cause
4) Sixty-two per cent of the fractures occurred near the knee joint
5) The cause of the bone rarefaction and of the fracture is discussed
6) Pyrexia and malaise can be the presenting signs of a fracture
7) Only 36 5 per cent of the fractures healed with excessive callus formation The reason for this exuberant callus is unknown but it may be an expression of the state of the metabolic flux in the bone at the time of the fracture or of excessive movement in the absence of sensation
8) An excessive amount of heterotopic bone occasionally forms after operations on the hips of these children (Figure 8)
9) The clinical and radiological picture of a fracture in these children can be confused with osteomyelitis, bone sarcoma, bone syphilis,

bone lesions of scurvy, neurotrophic joints and the "battered child syndrome"

10) As prophylaxis against fractures, the following measures are suggested

a) The use of beds in which the side bars are blocked by transparent plastic planks, and

b) The use of splints rather than plaster for immobilization wherever this is possible

SUMMARY

The fractures suffered by 130 children affected with myelomeningocele are studied

The relation to the level of neurological involvement, site of the fracture age of the patients treatment received and the possible deficiency of vitamin C is examined

The healing process in denervated limbs is discussed and prophylactic conclusions are drawn

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Figure 1 A lumbar myelogram showing a block to the flow of myodil of site A opposite L 2

the finger tips reached only to within ten inches of the floor A postural scoliosis convex to the left became more apparent Spinal extension was full Lateral flexion and lateral rotation were diminished on movement to the right O Connell s femoral stretch sign was present on the right side and there was some impairment of sensibility to pin prick on the lateral aspect of the right foot Straight leg raising on the left and right sides was 70° and Lasegue s sciatic stretch sign was absent There was weakness of dorsiflexion and eversion in the right ankle and foot All reflexes were normal and there was a flexor plantar response

Investigations

Further investig tions revealed a normal full blood count ESR and electrolytes Radiographs of the lumbo sacral spine were normal A lumbar puncture revealed a pressure of 60 mm of CSF recorded with free rise and fall on jugular vein com pression Microscopy of the CSF demonstrated less than one polymorph per mm³, less than one lymphocyte per mm³ and five RBC s per mm³ No micro organisms could be demonstrated on Gram stain and culture was sterile CSF protein was 345 mg per 100 ml and a Lange curve of 0011000000 was recorded Glucose and chloride levels in the CSF were not determined A lumbar myelogram showed a complete block to the cranial flow of myodil in both prone and supine positions at the level of the first and second lumbar vertebrae (Figure 1) A provisional diagnosis of an intradural space occupying lesion was made

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AN INTRADURAL EPIDERMOID CYST IN THE LUMBAR REGION

Case Report and Review of Current Aetiological Theories

ROBERT E PAGE

Accepted 13 iii 74

Dumeril (1807) was the first to report an epidermoid tumour, but Cruveilhier (1829) published a more comprehensive account and coined the term "tumeur perlee" to describe the gross appearance of this neoplasm Epidermoid tumours of the central nervous system are rare and represent less than one per cent of all brain tumours (Fleming & Botterell 1959), but their intraspinal appearance is even less common in forty-four patients with epidermoid tumours involving the central nervous system, MacCarty et al (1959) found only three in the spinal cord After searching the literature thoroughly, Manno et al (1962) found and classified only ninety epidermoid tumours of the spine More recently Reeves (1967) and others have reported isolated examples

CASE REPORT

In October 1971 a woman aged forty seven years complained of low back pain of two years duration The pain began suddenly when lifting a heavy weight and affected the lower lumbar region on both sides radiating down the posterior and lateral aspects of the right thigh Coughing sneezing and straining aggravated the pain, that was continuous in nature Before attending our clinic the patient had been given numerous forms of treatment bed rest daily spinal traction for two weeks back exercises and two caudal blocks These were of no benefit to her On the contrary, the caudal blocks that were performed in May and August 1971 aggravated her symptoms

Examination

Examination of the vertebral column revealed sacrospinalis spasm and limited spinal flexion in the lumbar region the lumbar lordosis was not obliterated and

ical layer and gives this as a reason for the preponderance of epidermoid, dermoid, teratoid and teratomatous tumours in the lumbosacral region A combination of the Holmdahl (1933) and the Rewcastle & Francoeur (1964) theories, that is, teratogenesis within a mass of caudally placed germinal cells, would appear to be a reasonable hypothesis to explain the origin, in congenital terms, of each of these tumours, but experimental proof would be difficult to obtain

Both clinical and experimental evidence for the production of iatrogenic tumours is vast and now unquestioned

Van Gilder & Schwarz (1967) have shown convincingly that central nervous system dermoids and epidermoids can be produced by skin implantation along the neuroaxis in albino rats and similar experiments by Oblu et al (1967) have led to the same conclusion

Blockley & Schorstein (1961), Choremis et al (1956), Oeconomos & Caracolos (1957), De Rougemont et al (1962) each have described young children with subarachnoid extramedullary epidermoid cysts, sometimes multiple, of the lumbar region and in all cases the children have received multiple (three to many) lumbar punctures during the treatment of meningitis Because the cysts were approximately at the sites of the lumbar punctures and because of their subarachnoid position and multiplicity, it is strongly suggestive that they arose from viable fragments of epidermis carried in by the lumbar puncture needles In this connection it is interesting to note that Gibson & Norris (1958) showed that in sixty per cent of skin punctures, a small piece of skin becomes detached and remains in the needle Since lumbar puncture needles carry a stilette, the possibility of introducing a fragment of skin into the subarachnoid space must be high

The growth rate of intraspinal epidermoid tumours is variable depending upon the aetiology Simple congenital epidermoid tumours, not associated with dermal sinuses grow slowly, as indicated by the twenty to twenty five year average latent period, before the onset of symptoms (List 1941) Gross (1934) in twenty patients with simple intraspinal epidermoid and dermoid tumours found the duration of symptoms to be ten years and the average age at operation thirty to forty years Congenital epidermoid tumours in association with dermal sinuses have a shorter latency (List 1941) indicating a more rapid rate of growth In those patients reported by Manno et al (1962) with both congenital epidermoid tumours, and dermal sinuses, the average age at operation was five years Where these two defects are apparent in the same patient the embryological malformation is likely to be of a

Operation

At operation an intradural tumour, intimately entangled with the nerve roots of the cauda equina was carefully dissected and removed intact. The tumour was located opposite the first and second lumbar vertebrae and was oval in shape, measuring approximately 1 cm by 2 cm

Progress

Post-operatively the patient made an uneventful recovery and was discharged on the fourteenth post operative day At routine out-patient follow up at one month and two months, the patient was well and without symptoms

Histology

Histological examination of the specimen revealed fragments of epidermis covered with numerous keratin squames with no skin appendages, a pathological diagnosis of Epidermoid Cyst was made Bacteriological culture was sterile

AETIOLOGY OF INTRASPINAL EPIDERMOID TUMOURS

It is stated by Reeves (1967) that epidermoid, dermoid, teratoid and teratomatous tumours arise from ectopic cell rests The cell rests may be deposited in an ectopic position by some defect in embryo formation and the tumours which develop are considered to be congenital Alternatively, the cell rests may be introduced into an intraspinal position by surgical intervention and the resultant tumours are then termed iatrogenic in origin

The ultimate nature of the congenital tumours appears to depend upon the state of development and nature of the cell rests, ectopic implantation in the embryo of primitive undifferentiated cells derived from all three germ layers may lead to teratoma formation Similarly, ectopic cells from two germ layers may produce teratoid tumours (Reeves 1967) It is currently accepted that congenital epidermoid tumours are formed by the investment of cutaneous epithelium during the closure of the medullary folds in the third to fifth week of embryonic life (Bostroem 1897)

However, in the case of teratomatous cysts Rewcastle & Francoeur (1964) dispute the aetiology of simple misplacement of normally developing cells and state that these neoplasms are a result of teratomatous development This suggestion is well substantiated by a demonstration of female sex chromatin in teratomatous cysts removed from male patients As yet, similar findings in epidermoid cysts have not been reported Holmdahl (1933) considers the caudal end of the cord to develop from a solid mass of germinal cells of no specific embryolog-

& Giest (1950) have described particularly those changes produced by spinal teratomatous tumours, stating that only fifty per cent of proven cases show plain X ray changes Calcified deposits are generally minimal or absent but a case reported by Moore & Walker (1951) showed massive intraspinal calcific shadows In the patient reported here, myelographic studies undoubtedly led to an early diagnosis The outcome is a testimony to the value of myelography in the presence of progressive symptoms and signs associated with a space occupying lesion in the spinal canal

At operation, total cyst excision was technically possible and preferred to cyst evacuation The latter method allows affected nerves to be decompressed, but Hullay et al (1962) have shown it to be followed by an early recurrence rate Although dissection of the tumour from the cauda equina proceeded without difficulty in this patient, it is important to note that Van Gilder (1967), using animals, has shown the pericystic collagen tissue to be locally invasive subarachnoid implants have been demonstrated to invade nerve roots However, a long remission may occur even with incompletely removed tumours (MacCarty et al 1959), presumably because of their slow growth rate

The removal of the intact cyst in the patient reported in this communication was probably a beneficial factor to her post operative recovery Verbiest (1939) postulated that cyst spillage can result in a meningeal reaction and arachnoiditis Similarly, Van Gilder (1967) noted on examining one of his animals sacrificed because of spasticity, that a cyst had ruptured and produced necrosis in the spinal cord nearby Craig (1943) noted this phenomenon as a post operative complication and thought it to be responsible for the poor operative results that he had obtained

The present author is of the opinion that excision, when not complete should be as wide as possible, but should not rupture the cyst or jeopardise apparently healthy nerve roots

SUMMARY

An intradural epidermoid cyst in the lumbar region of a forty seven year old woman is reported The importance of myelographic examination in patients suffering gradual symptomatic deterioration coupled with progressive physical signs is emphasized Current theories regarding the aetiology of epidermoid cysts are reviewed

marked degree and the initial cell rest may be of considerable size Early diagnosis, prompted by the existence of a dermal sinus plus an initially large epithelial cell rest may give a misleading impression of a more rapid growth rate Epidermoid cysts of iatrogenic origin produced by implantation, have been shown by Manno et al (1962) to have a relatively short latency and a mean period of 6 9 years between the initial surgical procedure and operative removal of a tumour

DISCUSSION

The aetiology of the epidermoid tumour presented in this case report is undoubtedly congenital Although two caudal blocks performed twelve months before the operation, may have been responsible for the introduction of skin fragments, albeit at a lower level, these could not have attained, according to the statistics quoted by Manno et al (1962), the size of the tumour removed at operation It is interesting to note that this congenital epidermoid tumour was unaccompanied by associated anomalies such as spina bifida or dermal sinus

In a small series of patients with intraspinal epidermoid tumour collected by List (1941) a male predominance was noticed but the larger series of Manno et al (1962) showed sex incidence to be equal By adding those patients who have subsequently appeared in Western literature to those figures quoted by Manno et al (1962) the distribution becomes forty six females to fifty three males including the case presented in this communication

Gross (1934) in a series of twenty intraspinal epidermoid tumours found the average duration of symptoms to be about ten years and Reeves (1967), although stating no precise period suggests that the prolonged and slow progression of symptoms is an important guide in the pre operative diagnosis of the tumour The patient presented here showed an unusually short history of only two years The relatively early diagnosis was made possible by recognition of a small but significant group of clinical signs and confirmation was secured by prompt myelographic investigation The straight X ray of the lumbo sacral spine in iatrogenic and simple congenital epidermoid cysts (in the absence of spina bifida occulta) appears to be of limited value for making an early diagnosis in that direct pressure producing sufficient vertebral erosion to appear on a plain X ray could be maintained only by a large epidermoid tumour The X ray changes produced by spinal tumours are well documented by Elsberg & Dyke (1934) and Hannan

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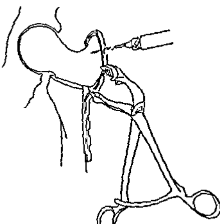


Figure 1 The compression is applied on the proximal trochanteric fragment and fixed to it with two screws The plate must sit tightly on the bone in order to prevent unwanted change of the position of the fragments

fragment The lower fragment is then fixed with a clamp against the plate and a compression device is applied (Figure 2) A full compression is applied and this is at its maximum when the plate begins to straighten This results in an elastic compression according to the elasticity of the stainless steel plate Even if the fragments should go into each other the compression continues because the plate tends to pull them closer together even after the screws in the lower fragment are screwed in After the compression is applied the screws in the lower fragment are applied according to Figure 2 The compression device is then removed and the

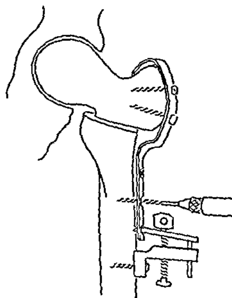


Figure 2 When the plate has been fixed to the upper fragment it is attached to the distal fragment and compression applied

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THE FIRST HUNDRED AND FIVE INTERTROCHANTERIC DISPLACEMENT OSTEOTOMIES PERFORMED WITH A NEW COMPRESSION PLATE

PENTTI SALENIUS

Accepted 18 viii 74

Despite recent developments in the treatment of painful osteoarthritis of the hip joint, particularly by means of artificial joints, intertrochanteric displacement osteotomy still has its place, especially in the treatment of young patients Stable internal fixation is an absolute necessity for complete and rapid post-operative recovery after intertrochanteric displacement osteotomy (Green 1967, Osborne 1964, Rosborough & Stiles 1967, Scott 1967)

In 1969, at the meeting of the Finnish Surgical Association, I introduced a new compression plate for internal fixation of intertrochanteric displacement osteotomy (Salenius 1970) The plate is made of stainless steel and is available in one size only, it is manufactured at present in England by Zimmer

OPERATIVE TECHNIQUE

Intertrochanteric displacement osteotomy is performed through a lateral incision It has been our custom to divide the ileopsoas tendon When the osteotomy has been performed the plate is applied to the proximal fragment so that its upper end goes over the greater trochanter (Figure 1) If the osteotomy has been made too low so that the proximal fragment is longer than the upper part of the nail the nail can be hammered lower down through the greater trochanter The plate is then fixed with compressing bone clamps against the greater trochanter and the upper screw in the proximal fragment is screwed in In the beginning ordinary A-O compression screws were used, but later compression screws manufactured by Zimmer England have been used because they have a lower screw head which does not irritate the surrounding tissues when the patient walks After the proximal screw is secured in its place the compressing clamp can be removed and the lower screw is fixed similarly after boring and applying threads for the screw with the AO instrumentation When the two upper screws are screwed in the plate rests firmly on the upper

Table 2 Hospitalization after operation

	No of patients	Male	Female
Less than 2 weeks	33	10	23
2-4 weeks	62	28	34
4-6 weeks	8	4	4
More than 6 weeks	1	1	–
Total	104	43	61

case a deep thrombosis developed in one leg In another a fracture of the femoral neck occurred during the operation Osteotomy led to consolidation but the femoral neck did not consolidate so that a total hip replacement was performed later It has been necessary to remove the lower screw of the proximal fragment in three cases because of the loosening of the screw, obviously during the application of the plate In two cases the entire plate has been removed In one case the plate had broken during the post-operative period In this case the plate was bent several times during the operation to find a proper angle for the



Figure 3 Intertrochanteric displacement osteotomy immediately after operation

Table 1. Distribution according to age

Age	No of patients	Male	Female
Under 30 years	4	–	4
30–39 years	5	1	4
40–49 years	19	8	11
50–59 years	32	18	14
60–69 years	34	14	20
70–79 years	10	2	8
Total	104	43	61

osteotomy completed If a varus or valgus position is required a corresponding wedge of bone is removed from either of the fragments The plate has then to be bent according to the desired position of the fragments Because of the mechanical factor resulting from the pull on the outer sides of both fragments this compression device has a slight tendency towards the valgus position but this can be prevented by a proper technique In all cases a suction drainage is applied postoperatively The patient stands up with two crutches the day following the operation The operated leg can be safely put on the floor and slight weightbearing allowed During the last few years I have allowed full weightbearing without crutches within four to six weeks after the operation However, some patients have walked, without permission, a few days after the operation without any harm to the internal fixation, so obviously the period for non weightbearing can be shortened in the future

We have now performed about 350 osteotomies with the new compression plate and this report deals with the first 105 osteotomies performed until the beginning of 1972 The osteotomies have been performed by several surgeons though 60 of the cases have been performed by the author

RESULTS

The material comprises 104 operated patients one of whom had a bilateral osteotomy so that in fact the total number of osteotomies was 105 Five of these were performed in a private hospital, the remainder in the Orthopaedic Hospital of the Invalid Foundation, Helsinki The age distribution of the patients is shown in Table 1 The mean age of the patients was 55 years, the oldest being 74 years and the youngest 20 years of age The majority of the cases were primary displacement osteotomies In four cases, however osteosynthesis was performed after failure of a previous osteosynthesis performed with another fixation method One patient died of pulmonary embolism 3 weeks after operation Mortality in this series was then 0 95 per cent In one



Figure 5 The osteotomy 16 weeks after operation The site of the osteotomy is hardly visible The remodelling has also been weightbearing for $2^1/_2$ months already

clearly apparent (Figure 3) An X-ray of the same case 6 weeks postoperatively reveals that the osteotomy site has become less and less clear and is now poorly visible on X ray (Figure 4) Periosteal callus is not visible but there is no doubt that at the point of the osteotomy consolidation is continuing In a later table I have chosen this point of development as the time of consolidation In the following X-ray 4 *months* after operation (Figure 5) *the osteotomy site has gradually* disappeared The patient has been moving without crutches 2 months before the last figure and full weightbearing has been allowed during the same period The times for consolidation in the entire series are shown in Table 3 We observe in the table that 62 cases consolidated in less than 2 months and the majority in less than 3 *Only in one case* did non union occur The rate of non union was thus 0 95 per cent This patient did not begin weightbearing on the operated limb and osteoporosis *developed causing instability* at the point of osteotomy a few months later This patient had taken small doses of cortisone because of her rheumatoid arthritis in the other joints The patient was re operated with a similar plate and consolidation took place within 2 months The observation period in the material was on the average 1 year

Figure 4 The osteotomy 6 weeks after operation The osteotomy site is disappearing The consolidation has obviously taken place This stage of consolidation has been taken as the time of union in Table 3



osteotomy Osteotomy led to consolidation however, and the plate was removed later

Post operative time spent in the hospital per patient is shown in Table 2 It will be noted that about one third of the patients went home less than 2 weeks after operation Patients received physiotherapy for mobilization of the hip and knee after operation

In the case of a stable osteosynthesis it is extremely difficult to judge the state of consolidation radiologically Figure 3 illustrates an osteot omy immediately after operation where the osteotomy surfaces can be sharply and clearly seen on an X ray and the site of the osteotomy is

Table 3 Period of consolidation in weeks

	Total hips	Male	Female
4–6 weeks	16	7	9
6–8 weeks	46	14	3?
8–12 weeks	32	18	14
Over 12 weeks	10	3	7
Non union	1 (0 95%)		1

4 weeks in 95 patients One patient died 3 weeks after operation with pulmonary embolism and therefore the death rate was 0 9 per cent In many cases the consolidation occurred very rapidly and was confirmed by radiology in less than 8 weeks in 62 patients Altogether 94 osteotomies consolidated in less than 12 weeks Only one case of non-union occurred in this series This patient was a fat female who had used cortisone for rheumatoid arthritis in other joints The non-union rate in this series was 0 95 per cent The recovery of the patients was rapid and hospitalization was short, and the new plate may therefore be *recommended for internal fixation of intertrochanteric displacement* osteotomies

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DISCUSSION

Intertrochanteric displacement osteotomy has given good results ac cording to many reports (Nissen 1963, 1964, 1966, Hirsch 1961, Saleniu et al 1971). Therefore it is still advisable to perform intertrochanteri displacement osteotomies especially in younger age groups, as we stil do not know the long-term results of total hip replacements For a successful recovery from the operation it is of the utmost importance that the osteosynthesis is stable and results in firm consolidation In many previous reports the non-union rate in intertrochanteric displacement osteotomy has varied between 6 and 10 per cent (Hirsch 1961, Green 1967, Rosborough & Stiles 1967, Scott 1967) The non-union clearly prolongs the rehabilitation of the patient and delays his return to work In this series of operations, which were performed with the new compression plate, the non-union rate was very low indeed as there was only one case of non-union in the series of 105 operations As the weightbearing could be started at an early stage, 4–8 weeks after the operation, the patients' rehabilitation was easy and the short non-weightbearing period did not result in osteoporosis in the operated limb Moreover, it has been seen clinically when the osteosynthesis is firm and stable that the initial recovery from the operation is rapid, the patients are almost pain-free after operation and their discharge from the hospital can take place within 2–3 weeks after the operation in many cases This compression plate does not require a very large amount of displacement and therefore a possible application of total hip replacement afterwards is easier than with many other internal fixation systems The osteosynthesis has been in some cases very firm as indicated by the fact that some patients have walked without support immediately after operation with no harm to the osteosynthesis According to the results reported in this series it is therefore quite obvious that the new compression plate has fulfilled the hopes placed upon it and the new compression plate may therefore be recommended for internal fixation of the intertrochanteric displacement osteotomy of the femur

SUMMARY

In this series the results of 105 intertrochanteric displacement osteotomies have been reported The internal fixation has been performed with a new compression plate The hospitalization after the operation has been very short, being less than 2 weeks in 33 patients and less than

One patient died 3 weeks after operation with

by radiology in less than 8 weeks in 62 patients Allose
omies consolidated in less than 12 weeks Only one case of non union occurred in this series This patient was a fat female who had used cortisone for rheumatoid arthritis in other joints The non union rate in this series was 0 95 per cent The recovery of the patients was rapid and hospitalization was short, and the new plate may therefore be recommended for internal fixation of intertrochanteric displacement osteotomies

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INTERTROCHANTERIC OSTEOTOMY OF THE FEMUR WITH AO-TECHNIQUE FOR OSTEOARTHRITIS OF THE HIP JOINT

A Clinical Follow-up Study Five Years after Surgery

SVEN S OLSSON

Accepted 1 x 74

Over the last few years the dominating position of total arthroplasties has been substantiated in the surgical treatment of osteoarthritis of the hip Although most reports so far have dealt with primary results, information is now appearing concerning the reliability of these results over a longer period of time, giving a clearer picture of the advantages and disadvantages of total hip replacement Charnley & Cupic (1973) report 9 6 per cent of total failures after nine to ten years' follow-up time and Chapchal et al (1973) recommend a lower age limit of 60 to 65 years for total hip arthroplasty The question then arises of how to treat patients in younger age groups with hip osteoarthritis causing pain and functional impairment Charnley (1970) recommends expectation whereas others, e g Huggler (1971) and Detenbeck et al (1972), advocate intertrochanteric osteotomy of the femur in these cases

It has been shown that intertrochanteric osteotomy will bring about relief or abolition of pain in over 80 per cent of the cases (Hirsch & Goldie 1968, Gudmundsson 1970 Morscher 1971, Hansen et al 1973) and an arrest or reversal of the osteoarthritic process may be expected in a majority of cases as shown radiologically (Osborne & Fahrni 1950, Duthie & Howe 1963, Hirsch et al 1972) With this background it was considered essential to evaluate the clinical results of the operations performed after introduction of the AO-technique at our clinic in August 1966, and to present them with special consideration of the results of total hip replacement as well as the natural history of osteoarthritis of the hip

MATERIAL

The follow up study covers the intertrochanteric femur osteotomies, performed with the AO technique, in cases of primary and secondary osteoarthritis of the hip joint at the Department of Orthopaedic Surgery, University of Gothenburg, from August 1966 through 1968 During the end of the period the first two total hip replacements were performed at this clinic Except for arthrodesis, which was reserved for particularly selected cases, no other operative methods were in use The indications for osteotomy were essentially identical with those reported in an earlier material (Hirsch & Goldie 1968), with spontaneous pain as the main criterium for surgical intervention.

The number of patients amounted to 110, representing 115 osteotomies, 28 of the osteotomies had to be excluded from the follow up study for various reasons Eleven patients, representing 11 hips were dead, in no case from a cause associated with the operation Eleven hips had been re-operated with total hip replacement and should be considered in the following as failures. In addition, six patients, all operated on one side only, had to be excluded for various reasons. Two patients could not be examined because of old age and general weakness, two could not be traced one had emigrated and one refused to appear for examination In the re-operated cases the records reveal that the patients have had a period of generally one to three years of relative or total relief from pain following osteotomy As regards four of the remaining patients, information could be obtained from nursing staff and relatives Two patients were completely free of pain in their operated hips one was partially relieved but had pain during activity and one had pain at rest 87 operated hips in 84 patients remained for follow up 30 were men and 54 women five of whom were bilaterally osteotomized during the period Two of the bilateral cases had been re operated on one side with total hip replacement 47 of the osteotomies were on the right side and 40 on the left The age of the patients at operation ranged from 38 years and 9 months to 80 years and 10 months with a mean age of 59 7 years, the age distribution being shown in Table 1

Table 1 Age at operation

Age (years)	40 or less	41–50	51–60	61–70	71–80
No of hips	2	12	35	30	8

73 hips were classified as primary osteoarthritis and 14 as secondary to dysplasia (seven hips) Perthes disease (three hips) congenital luxation, treated conservatively in childhood (three hips) and epiphyseolysis (one hip) In three cases operations had been done on the same hip before, Voss' operation, acetabuloplasty and transposition of the greater trochanter in one case each

In the absence of a uniform pre operative assessment of the patients' conditions, close questioning during the follow up has completed and confirmed the information available from the patients records to give a general picture of the pre operative symptoms constituting the indication for the operations

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In the absence of a uniform pre operative assessment of the patients' conditions close questioning during the follow up has completed and confirmed the information available from the patients' records to give a general picture of the pre-operative symptoms constituting the indication for the operations

Pain

In 65 cases the patients had *spontaneous* pain which with few exceptions was characterized as 'severe' and had lasted *for at least half a year* Pain *usually* disturbed sleep and *greatly reduced physical activity* 21 patients had severe pain *that appeared during walking* and *other activities* but as a rule was relieved or disappeared during rest The *duration of these symptoms* was *in three cases* between a half and one year and in 18 *cases two years or more*. Only in one case was pain insignificant, stiffness and *weakness being stated* as *the main* symptoms.

Range of movement

The range of movement in the hip *joint and the radiological* state were not determining factors in *selecting patients for* operation The wide margin of error and variations between *different examiners in* measuring hip joint movement precludes any *reliable comparison in this respect between* pre-operative data and those obtained at the follow *up examination* The majority of patients stated a slight or moderate *improvement of the range* of movement after the operation In no case had it been *normal before operation and in* a considerable number of the cases restriction of movement *was so great* that with the principles of today it would have made *the patients candidates for* total hip replacement rather than osteotomy

Radiology

Radiological changes varied *from slight* narrowing of the joint space to advanced deterioration with *deformation of* caput and acetabulum Most hips showed a *radiologically* advanced *osteoarthritis with marked* narrowing or complete obliteration *of the joint space* and with *sclerosis and cysts* in caput and acetabulum

Walking

To facilitate the assessment of walking Charnley (1972 divided his material into three categories *A* denoting *unilateral hip involvement* and absence of other disabilities *interfering with walking B bilateral hip involvement and C* presence *of some other factor contributing to the impaired function* of walking In the present series *36 patients belonged to category A 34 to category B and 14 to* category *C* Of the 34 bilateral cases 19 *had had both hips operated on* at the time *of the follow up* examination *Osteotomy* on the *opposite hip had been done* in six cases before and in six cases *after the period under discussion* Five patients had had bilateral osteotomies during the *period and two of these* had later been re-operated on one side with *total hip replacement* The remaining two patients had been operated on the opposite side with total *hip replacement* and *arthrodesis* respectively, as primary interventions

Operative technique

At the 87 operations included in this study different types of AO angulated plates have been used *the angle varying from 90° to 120° In all plates the difference in level between the vertical leg and the base of the upper leg* was 10 mm thus confining the medial displacement of the femoral shaft to 10 mm provided

the plate was optimally placed Medial displacement only was carried out in 36 cases and a wedge was removed in 51 cases to achieve angulation in the case of contracture or to provide maximal congruity between the cut surfaces In 46 cases *the base of the wedge was directed medially* and in five cases laterally or anteriorly The height of the base varied from a few millimetres to $1^3/_4$ cm in most cases it was about ½ cm In six cases because of adduction contractures, a tenotomy of the iliopsoas tendon was also done Compression of the osteotomy using the AO compression device was consistently carried out Permanent suction drainage was always used for one to two days postoperatively In one case the internal fixation was supplemented with a plaster cast for six weeks and the patient was confined to bed for three months All other patients were mobilized after an average of five days in bed and walked with the aid of two crutches without weightbearing for two to three months

Time of healing and rate of pseudarthrosis

Radiological signs of healing were established and full weightbearing was allowed in all cases except four after an interval from the time of operation ranging from three to seven months In two of these four cases spontaneous healing took place after nine months and two years respectively and in the other two cases pseudarthrosis developed requiring re operation Union was ultimately achieved after one year and four months in one case and two years and nine months in the other

Early complications

Complications during the early postoperative course were diagnosed in ten patients Four cases of crural thrombosis and two cases of suspected pulmonary embolism were treated for a few weeks with anticoagulants and no residual symptoms appeared Two superficial infections healed after antibiotic treatment for two weeks One case of deep infection occurred and was not cured until the fixation instrument was removed eight months after the osteotomy Union of the osteotomy took place at the normal time In one case an adduction contracture developed postoperatively and was treated with adductor tenotomy four months after the osteotomy with a satisfactory and permanent result

Removal of fixation instruments

In addition to the two pseudarthroses the fixation instruments have been removed in 25 cases owing to infection in one case and local pain or tenderness in the rest The time interval from the osteotomy to the removal varied between six months and five years with an average of two years

METHOD OF INVESTIGATION

The follow up examination took place from August through December in 1973 The follow up times varied between four years and eleven months and seven years and two months the mean follow up time being five years and eight months The questioning and examination were based upon the numerical rating system for

Table 2 Assessment of pain at follow-up 5 years after intertrochanteric osteotomy with the AO technique in 87 hips, compared with an earlier series of intertrochanteric osteotomies (Goldie et al 1973) and to one of total hip replacements (Patterson & Selby Brown 1972)

Pain	Points	Present series		Goldie et al 1973*	Patterson & Selby Brown 1972†
		No of hips	%	%	%
Severe, spontaneous	1	7	8 0	16	2.7
Severe on attempting to walk Prevents all activity	2	4	4 6	2	5 5
Tolerable, permitting limited activity	3	12	13 8	15	13 3
Only after some activity. Disappears quickly with rest	4	24	27 6	15	21 5
Slight or intermittent Pain on starting to walk but getting less with normal activity	5	16	18 4	5	28 0
No pain	6	24	27 6	47	29 0
Mean value, points		4 3		4 3	4 5

* Intertrochanteric osteotomies 81 cases
† McKee-Farrar total hip replacements, 368 cases
(Decimals of original are rounded off)

assessment of results after hip joint surgery described by Merle d'Aubigné & Postel in 1954 and modified by Charnley in 1972 The examiner had not been engaged in the operation or after-treatment of any of the patients

RESULTS

In Tables 2–4 the results with reference to pain, range of movement and ability to walk are presented, together with corresponding data from a follow-up examination of 81 osteotomies made before the AO-technique came into use (Goldie et al 1973) and from a representative material of total replacements, including 368 operations with the McKee-Farrar technique (Patterson & Selby Brown 1972) The mean observation times in these series were 8 7 and 1 4 years, respectively, and both have been assessed according to the same rating system as the present series, thus providing a condition necessary for comparing the results (Andersson 1972)

In the present series all patients who stated spontaneous or more or less continuous pain have been rated as Grade 1, considering the

Table 3 Assessment of total range of movement at follow-up 5 years after intertrochanteric osteotomy with the AO technique in 87 hips compared with an earlier series of intertrochanteric osteotomies (Goldie et al 1973) and to one of total hip replacements (Patterson & Selby Brown 1972)

Range of movement, degrees	Points	Present series				Goldie et al 1973†	Patterson & Selby Brown 1972§
		Opposite hip Cat. A+C*		Operated hip			
		No	%	No	%	%	%
0- 30	1	–	–	8	9	7 5	1 6
31 60	2	–	–	12	14	16	1 9
61 10	3	–	–	18	21	34	7 3
101 160	4	4	8	41	47	33	56 3
161 210	5	27	54	8	9	7 5	27 7
211 260	6	19	38	–	–	4	5 2

* Category "A" = unilateral hip disease Category C = unilateral hip disease plus other disorder impairing walking

† Intertrochanteric osteotomies 81 cases

§ McKee Farrar total hip replacements 368 cases
(Decimals of original are rounded off)

Table 4 Assessment of ability to walk at follow-up 5 years after intertrochanteric osteotomy with the AO technique in 87 hips compared with an earlier series of intertrochanteric osteotomies (Goldie et al 1973) and to one of total hip replacements (Patterson & Selby Brown 1972)

Ability to walk	Points	Present series				Goldie et al. 1973†	Patterson & Selby Brown 1972§
		Total		Cat. A*			
		No	%	No	%	%	%
Bedridden or few yards two sticks or crutches	1			–		1	3 5
Time and distance very limited with or without stick.	2	24	28	3	8	20	24 0
Limited with one stick (less than 1 hour) Difficult without a stick. Able to stand long periods	3	12	14	4	11	26	27 0
Long distances with one stick. Limited without a stick	4	21	24	11	31	22	22 3
No stick but a limp	5	14	16	9	25	23 5	20 4
Normal	6	16	18	9	25	7 5	3 0
Mean value points		3 8		4 5		3 7	3 4

* Unilateral hip disease † and § See notes under Table 3

Table 5 Use of stick at follow-up 5 years after intertrochanteric osteotomy with the AO-technique in 84 patients

Use of stick	Number of patients		Percentage	
	Total	Category A*	Total	Category A*
Two sticks always	6	1	7 1	2 8
One stick always	12	2	14 3	5 6
One stick outdoors	36	15	42 9	41 6
No stick	30	18	35 7	50 0

* Unilateral hip disease.

term "spontaneous" rather than "severe" Four of the seven Grade 1 patients claimed that pain was less pronounced than before operation and all could perform light household work or a comparable activity Only one patient stated that pain was worse than before operation

The range of movement represents the sum of degrees of movement in all three standard directions For comparison the range of movement in the opposite hip is also accounted for, excluding cases with bilateral hip joint affection The average range of movement in the operated hips was 93° Anchylosis was found in two hips

In Tables 4 and 5, showing walking capacity and use of walking aids, category "A" has been accounted for seperately in addition to the total material

Table 6 shows the patients' own overall evaluation of the results of the operation

In Table 7 eight old-age pensioners are excluded Six months' absence from work caused by the actual disease has been chosen as a limit after which the inability to work cannot be regarded as tem-

Table 6 Patients own overall evaluation at follow-up 5 years after intertrochanteric osteotomy with the AO technique in 87 hips compared with an earlier series of intertrochanteric osteotomies (Goldie et al 1973)

Patients' evaluation	Present series		Goldie et al 1973*	
	No of hips	%	No of hips	%
Worthwhile	73	84	68	84
Not worthwhile (10) and undecided (4)	14	16	13	16

* Intertrochanteric osteotomies

Table 7 Working capacity of 76 patients before operation and at follow-up 5 years after intertrochanteric osteotomy with the AO technique Eight old age pensioners excluded from total series

efore operation		At follow up						
	No of patients	Not at work	Changed to lighter work	Returned to same work	Present occupation Heavy	Light mobile	Sitting	House hold
At work or on sick list less than 6 months	53	15	3	35	1	9	3	25
On sick list more than 6 months or receiving ..ability pension	23	19	2	2	1	–	–	3

Table 8 Presence of hip joint contractures at follow-up 5 years after inter trochanteric osteotomy with AO technique in 87 hips compared with non surgically treated osteoarthritis in 91 hips (Danielsson 1964)

ntractures egrees)	Prescut series percentage			Danielsson (1964), percentage		
	Flexion	Rotation	Adduction	Flexion	Rotation	Adduction
l	66 7	77 0	97 7	27 0	62 6	78 0
l 15	28 7	18 4	2 3	28 4	13 0	16 3
6-30	4 6	4 6	–	33 3	19 5	5 7
3-45		–	–	8 9	4 1	–
6-50	–	–		2 4	0.8	–

porary considering the nature of disease Six patients under the heading Not at work had returned to work after operation for periods of at least two years but had retired at the time of follow up, four of them for reasons other than hip joint affection

In Table 8 the presence of contractures in the present series is accounted for together with the corresponding data from a material of non surgically treated patients with osteoarthritis of the hip presented by Danielsson (1964)

Trendelenburg's sign was negative in 47 cases and positive or questionable in 40

A shortening of the leg was found on the operated side in 19 of the 65 patients who had not been subjected to operation on the opposite

hip In nine cases the leg length discrepancy amounted to 3 cm or more (maximally 5 cm), the average discrepancy being 1 2 cm

DISCUSSION

When comparing the present material with others, the eleven cases that have been re operated with total hip replacement should be taken into account as failures On the other hand there is strong support for the assumption that the results will not deteriorate further with the passing of time (Goldie et al 1973) Two points concerning the material deserve special attention For the first, the operations were performed with today's osteotomy technique but with yesterday's indica tions for osteotomy, as the selection of patients made possible with the introduction of total arthroplasty was not possible during the period under discussion For the second, obviously not less than three fourths of the cases in the material would have been classified pre operatively as Grade 1 with regard to pain using the same principles for assess ment as in the follow-up This remarkably high figure can be explained by a generally restrictive attitude to surgical treatment of hip osteoarthritis in our clinic during the period under discussion, with the preference being for a conservative regimen in cases without severe spontaneous pain The results in the present series, expressed in general terms such as "patients' own overall evaluation", are on a level with other reports of results after osteotomy The number of totally pain-free patients, however, is remarkably small A comparison with the report by Goldie et al (1973) (Table 2) of an earlier operated series might give an indication of how to explain this, the only fundamental difference between the two materials being the operative techniques employed The earlier material was operated with a tech nique involving a considerable medial displacement of the femoral shaft and often also a marked displacement in varus The fixation instruments achieved a relatively incomplete stability and secondary dislocation often accentuated the varus angulation In the present series the medial displacement in most cases has been less than 1 cm and only slight or moderate angulations have been made The stability of the fixation has prevented secondary dislocation

The significance of displacement and angulation in the osteotomy has been discussed by several authors Adam & Spence (1958), Lucht & Tarp (1967) and Appel & Friberg (1973) found no evidence that the amount of medial displacement of the femoral shaft would influence

the result Nissen (1963) noted that some change of alignment in the osteotomy appears to be essential for its effect Harris & Kirwan (1964) found indications that a varus osteotomy would stimulate healing of the osteoarthritic process more effectively than an osteotomy without angulation or with valgus angulation Vasey (1971) in a radiologic study including 2159 intertrochanteric osteotomies also found regression of osteoarthritic changes in a higher percentage of cases after varus osteotomies than after valgus or medially displaced osteotomies The importance of improving joint congruity by angulation in the osteotomy with the guidance of pre-operative radiographs in different positions of abduction and adduction in the hip joint is stressed by many authors, e g Pauwels (1961), Blount (1964), Knodt (1964), DePalma et al 1970), Detenbeck et al (1972) and Grundhöfer (1973)

When comparing, in the present series, the group of 46 hips in which a varus angulation was made by removal of a wedge, with the 36 hips in which only medial displacement was made, it is found that in the former group 35 *per* cent and in the latter group only 19 per cent are totally pain free The differences within the other grades of pain, however, are not clear cut

To evaluate the benefit of operation, one must be able to answer the question as to what course the disease would have taken without surgical intervention *The natural history of coxarthrosis, however,* has not been sufficiently studied to allow a definite answer Danielsson (1964) studying the course of 91 non operated cases for a ten-year period, found that two thirds reported a decrease of pain 15 per cent of the hips were anchylotic, compared with 2 out of 87 in the present material As indicated by Table 8, the reduction in pain in the non-operated cases was attained at the cost of a relatively large loss with regard to movement Pearson & Riddell (1962), following the course of primary coxarthrosis in 400 patients for periods of from 4 to 15 years, found only seven hips that became painless during the period The average time from onset of pain to almost complete loss of movement in the hip was 8 years Regarded against this background, the results of intertrochanteric osteotomy are certainly encouraging

SUMMARY

87 intertrochanteric osteotomies out of a total material of 115, performed from 1966 through 1968 with the AO technique, have been

examined with an average observation time of five years and eight months.

Subjectively satisfactory relief of pain or total absence of pain was found in 84 per cent. The total range of movement exceeded 100° in 56 per cent One third of the patients never used walking aids and 18 per cent walked without a limp In two cases pseudarthrosis had developed; both healed after re-operation

The methods of assessment employed facilitate comparisons of the results with those of other methods of surgical treatment of coxarthrosis It appears justifiable to regard intertrochanteric osteotomy as a valuable method for surgical treatment of coxarthrosis, especially in the cases where limitation of movement is not disabling

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examined with an average observation time of five years and eight months

Subjectively satisfactory relief of pain or total absence of pain was found in 84 per cent The total range of movement exceeded 100° in 56 per cent One third of the patients never used walking aids and 18 per cent walked without a limp In two cases pseudarthrosis had developed both healed after re operation

The methods of assessment employed facilitate comparisons of the results with those of other methods of surgical treatment of coxarthrosis It appears justifiable to regard intertrochanteric osteotomy as a valuable method for surgical treatment of coxarthrosis, especially in the cases where limitation of movement is not disabling

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PATIENTS AND METHODS

Patients

Forty two patients suffering from hypertrophic osteoarthritis underwent hip alloarthroplasty. The surgical approach was anterolateral with a Müller type prosthesis (4 patients) or posterolateral with a Mckee type prosthesis. Both types of prosthesis were cemented with Palacos ®, a bone cement on methylmethacrylate base (Kulzer Cie., Bad Homburg, West Germany). The joint capsule was excised *in toto*. Postoperative care was the same for both groups of patients and consisted of wound drainage for 48 hours, a hip spica for 5 days and traction in abduction and extension for 5 days. Anticoagulants were given from the first postoperative day; isometric static exercises were also started at this time. Walking without weightbearing, with two English canes, was started 5 days after surgery. From the 10th postoperative day the patients did active hip exercises and exercises with weightbearing.

The patients were randomly divided into a group receiving EHDP (20 patients) and a control group (22 patients). The groups were comparable with respect to type of operation, sex and age distribution. The age in both groups averaged 65 years.

Experimental details

The experimental patients received 20 mg per kg per day of EHDP divided into three equal doses and administered orally 30 minutes before meals.

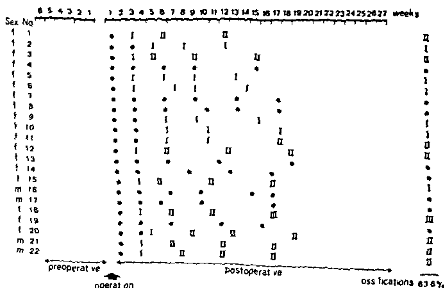


Figure 1. Development of ossifications after total hip replacement. Symbols at dates of low kV radiography refer to absence of ossification (closed circles) or presence of ossifications of grade I, II or III respectively.

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EFFECT OF A DIPHOSPHONATE ON PARA-ARTICULAR OSSIFICATION AFTER TOTAL HIP REPLACEMENT

O L M Bijvoet, A J G Nollen, T J J H Slooff & R Feith

Accepted 8 ii 74

In recent years para-articular ossifications have been recognized with increasing frequency as a complication of total hip alloarthroplasty (Wilson et al 1972, Patterson & Brown 1972, Nollen & Slooff 1973) These ossifications first become visible on low kilovoltage X-rays 2 to 3 weeks after surgery as ill-defined opacifications of mottled appearance in the gluteal and/or psoas region With time they may develop into bony bridges between the femur and pelvis Their appearance is often associated with pain and slight swelling of the hip without redness, fever or signs of infection and may occasionally, over a period of 12 weeks, lead to severe limitation of passive and active hip movement Some degree of ossification was seen in about 50 per cent of our patients and severe loss of function occurred in 7 per cent (Nollen & Slooff 1973) Histologically the lesion resembles that seen in myositis ossificans and paraosteoarthropathy, it consists of normally mineralized osteoid and a woven bone structure which is remodelled to trabecular bone

There is no known therapy, and hitherto no acceptable suggestions for treatment have been presented in the literature Because of the resemblance to myositis ossificans and because it has been suggested that the diphosphonate EHDP (disodium ethane-1-hydroxy-1, 1-diphosphonate) retards mineralization of the ectopic bone matrix in myositis ossificans (Russell & Smith 1973), we investigated the effect of EHDP on the development of these para-articular ossifications

Table 1. Effect of total hip replacement on pain and mobility in patients treated with EHDP and in controls.

Pain	improved	unchanged	worse
Control	17	5	0
EHDP	18	1	1

Joint mobility	good (100–200°)	fair (50–100°)	poor (0–50°)
Control before	4	11	7
after*	3	13	6
EHDP before	4	4	12
after**	17	3	0

* $P > 0.1$ ** $P < 0.001$

sections were stained (Schenk 1965) and the volume percentage of cancellous bone consisting of *uncalcified osteoid was assessed according to Merz & Schenk (1970)*. Student's t test was used to calculate the probability levels of the means and χ^2 for the fit of assumed distributions to actual data.

A systematic check on toxicity of EHDP included leucocyte and thrombocyte counts, examination of urinary sediment and protein excretion and measurements of serum alkaline phosphatase and 5-nucleotidase. *No adverse effects were noted.*

RESULTS

Development of ossification (Figures 1 and 2). Thirteen out of 22 control patients developed visible ossification between 2 and 6 weeks after surgery. Only two out of 20 EHDP-treated patients developed visible ossification during the diphosphonate treatment, but two to three months after discontinuation of EHDP, ossifications had appeared *in 11 out of 20 patients*. They often became visible on radiograms taken 2 weeks after treatment was stopped. The difference between patients receiving EHDP and the control group was significant at 6 weeks ($P < 0.001$) and 12 weeks ($P < 0.01$). At 27 weeks ossification occurred equally in both groups ($P > 0.5$). *There was an important* subjective difference between the two groups. *In contrast to* the control group, the appearance of ossification after *discontinuation* of EHDP was never associated with pain or swelling of the hip in the treated patients.

At three weeks after surgery, the normal time *for* ectopic ossifications to become visible on X-rays, there was no significant *rise of*

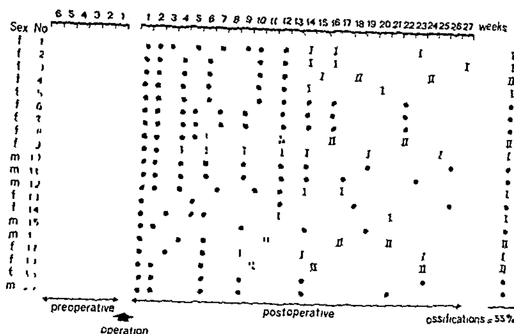


Figure 2 *Development of ossifications after total hip replacement in EHDP treated patients Shaded area refers to period of treatment For other symbols see legend to Figure 1*

Treatment was started 6 weeks before surgery and continued until the end of the sixth (7 patients) or twelfth (13 patients) postoperative week In all patients low kV radiograms were made at regular intervals until approximately the 24th post operative week (Figures 1 and 2) and assessed for the presence of ossification Four grades of ossification were defined as follows

- *grade 0* no ossifications visible
- *grade I* ossifications in gluteal area only, ill defined and without distinct bony structure
- *grade II* . ossifications in gluteal and psoas regions ill defined but often having a more distinct structure
- *grade III* complete bony bridges between femur and pelvis in gluteal and psoas regions with normal bone structure

Joint mobility and pain were assessed immediately before and 6 months after surgery Range of motion, expressed in degrees, was defined as the sum of mobility in the sagittal, frontal and rotational plane and was used to describe the functional results The results were then classified as good (100–200°) fair (50–100°) or poor (0–50°). In eight LHDP treated patients plasma creatinine (alkaline picrate method) and phosphate concentrations (Summer 1944) and renal phosphate reabsorption activity (Bijvoet et al 1969) were assessed immediately before and six weeks after the initiation of treatment

Six control patients allowed an iliac crest biopsy at the time of the operation and five LHDP-treated patients agreed to have this done at the time of the operation and at the end of treatment (three months after surgery) Undecalcified

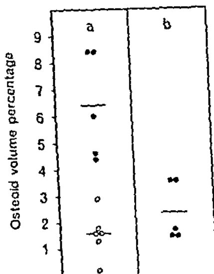


Figure 4 Osteoid volume percentage in iliac crest biopsy taken during the operation (a) and 3 months after surgery (b) in control patients (open circles) and in patients treated with EHDP (closed circles)

tion rate because serum creatinine concentrations remained unchanged ($P > 0.5$)

The ratio of phosphate to creatinine clearance did not change ($P > 0.5$) but it should now be well-known that this ratio in the presence of a changing serum phosphate does not offer useful information on tubular phosphate reabsorption (Bijvoet et al 1969) Serum phosphate and renal tubular reabsorption of phosphate showed normal values again after the EHDP treatment was ended

Iliac crest biopsies (Figure 4) In iliac crest biopsies from treated patients, taken at the time of the operation (after 6 weeks of EHDP treatment), the percentage of bone volume consisting of uncalcified osteoid was considerably higher than in the control patients ($P < 0.01$) Surprisingly, in biopsies taken 3 months after surgery, when EHDP treatment had not yet been discontinued, the volume percentage had normalized ($P > 0.05$)

DISCUSSION

Diphosphonates may prevent soft-tissue calcification induced experimentally in animals (Fleisch et al 1970) EHDP has been used in myositis ossificans progressiva to prevent progression in active cases and to prevent recurrence after removal of established ectopic bone in adults The results have recently been reviewed by Russell & Smith (1973) Their provisional conclusion is that there is no definite

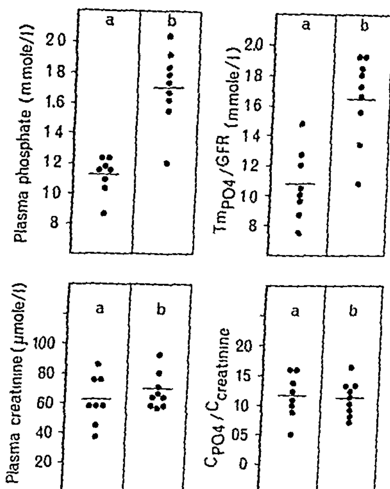


Figure 3 The fasting plasma phosphate concentration phosphate reabsorption activity (Tm_{PO_4}/GFR) plasma creatinine concentration and the ratio of phosphate to creatinine clearance ($C_{PO_4}/C_{creatinine}$) at the time of surgery in control patients (a) and in patients pretreated for 6 weeks with EHDP (b)

serum alkaline phosphatase, creatinine phosphokinase (CPK), and lacticdehydrogenase (LDH) in either of the two groups

Joint mobility and pain (Table 1) Preoperative joint mobility was impaired to a similar extent in the control and the EHDP-treated group Final mobility was significantly better in the EHDP group, whereas there was no overall improvement in the control group Pain however was relieved in both groups to a similar extent

The serum phophate concentration (Figure 3) increased significantly during EHDP treatment ($P < 0.01$) The elevation was due to an increase ($P < 0.01$) in the activity of renal tubular phosphate reabsorption (Tm/GFR) There was no associated change in glomerular filtra-

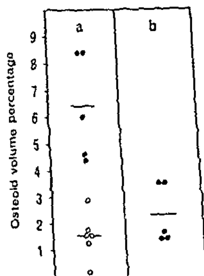


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evidence to show that such treatment causes either regression of established ectopic bone or increased mobility of joints not operated upon When a joint in such patients is operated on there is no evidence that EHDP inhibits the reformation of the ectopic bone matrix itself but it may be effective in delaying the calcification of this matrix There is no way to assess in these patients whether the delay in calcification has a beneficial effect on joint mobility

The present study describes the effect of EHDP on a group of non-septic ectopic ossifications of the locomotor apparatus that are comparable to the ossifications around large joints occurring in myositis ossificans or in the so-called paraosteoarthropathies observed in association with paraplegia (Nollen & Slooff 1973) However in contrast to these conditions, the occurrence of para-articular ossifications in total hip replacement is sufficiently frequent and predictable to offer the opportunity of a controlled study and to allow quantitative assessment of results

Our data demonstrate that continued administration of EHDP did significantly reduce the frequency of radiologically visible ossification after alloarthroplasty The effect persisted for at least three months, the maximum duration of EHDP-treatment However, the treatment did not affect the underlying lesions because ossifications became visible within a few weeks after discontinuation of treatment We therefore conclude that EHDP-treatment does not prevent the formation of ectopic bone-matrix, but only delays the mineralization of this matrix This effect can only be maintained by continuing the EHDP-administration, because when the drug was discontinued earlier than 3 months after surgery, ossifications reappeared earlier The normal time for these abnormalities to appear in the controls was within 1 to 3 weeks after surgery In contrast to the control patients, the appearance of ossification was not associated with pain in EHDP-treated patients

The ultimate frequency of the occurrence of ossifications was not significantly different However, there were two important differences between treated and control patients Firstly the treated patients did not experience pain Secondly the ultimate function of the hip of the treated patients was significantly better than that of untreated patients In fact the functional results of alloarthroplasty were greatly improved and had become optimal The reason for this may be that mineralization of the lesions had been delayed until after the patients were fully mobile and could exercise without pain

The development of an excess of uncalcified osteoid is a recognized complication of EHDP treatment and this was visible in our patients too We cannot explain why after 18 weeks of treatment the amount of osteoid in the iliac crest biopsy was actually less than after 6 weeks whereas no calcification around the hip had occurred Russell & Smith did not find evidence of a mineralization disorder in the bone of the normal skeleton of a patient with myositis ossificans treated with EHDP, who died six months after surgery, whereas tissue excised at the site of the operation showed only a partially mineralized matrix (Russell & Smith 1973) A possible explanation is that EHDP delays but does not prevent mineralization of newly formed normal bone and that the final reduction of the osteoid excess reflects a reduction of the rate of bone remodelling The latter effect of EHDP may be responsible for its beneficial effect in Paget's disease

The only other abnormality we found was an elevated serum phosphate concentration due to an increased renal tubular phosphate reabsorption in the kidney This confirms the findings of Recker et al (1973) who also reported that the renal tubules of EHDP-treated patients still respond normally to exogenous parathyroid hormone

Since this study we have reoperated patients who after a period had experienced considerable loss of hip function due to ectopic ossification Treatment with EHDP from 6 weeks before until 3 months after operation has resulted in optimal postoperative results We conclude that treatment with EHDP possibly in conjunction with adequate exercise considerably increases the functional results of total hip replacement Our results also suggest that even though EHDP does not prevent the recurrence of ossification after reoperation in myositis ossificans there is hope that these patients may yet gain in mobility and that treatment of such patients need not be prolonged indefinitely when the disease is in a quiescent phase

SUMMARY

Forty two patients underwent total hip alloarthroplasty Twenty of these patients were selected at random and received disodium ethane-1 hydroxy 1 1 diphosphonate (EHDP) orally from 6 weeks before the operation until 6 (7 patients) or 12 weeks (13 patients) after surgery Some degree of para articular ossification developed in 13 out of 22 control patients EHDP treatment delayed the radiological appearance of ossification but did not prevent its occurrence after treatment was

stopped However the treatment did prevent impairment of mobility as a result of ossification and considerably improved the functional results of total hip replacement These findings indicate that EHDP may also be an effective adjunct to surgical treatment in myositis ossificans EHDP treatment raised the plasma phosphate concentration by increasing renal tubular phosphate reabsorption Iliac crest biopsies showed development of excess uncalcified osteoid, this effect was however transient

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OPERATIVE TREATMENT OF CONGENITAL PSEUDARTHROSIS OF THE TIBIA

Factors Influencing the Primary Result

KJELD SKOU ANDERSEN

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Congenital pseudarthrosis of the tibia is a rare condition of unknown aetiology. A large number of operative methods have been suggested for its treatment, "establishing the fact that there is some doubt concerning the best form of treatment and emphasizing the need for systematic treatment continued until the completion of bone growth" (Van Nes 1966).

Interest in the phenomenon has increased. During the past 25 years more than 50 papers have appeared in English, German and French. However, the therapeutic problems still remain unelucidated. It therefore seemed of interest to publish a material collected from several countries in an attempt to elucidate whether some operative methods were better than others or whether the therapeutic results were influenced by some special factors, operative or non operative.

CLINICAL MATERIAL

Congenital pseudarthrosis of the tibia is taken to mean all congenital fractures of the tibia as well as pseudarthroses of the tibia after a pathological fracture or osteotomy on a lower leg with congenital anterior angulation. Cases of generalized skeletal diseases were excluded if these diseases could be assumed to have contributed to the occurrence of fracture or pseudarthrosis.

From 18 orthopaedic departments and hospitals in Denmark, Norway, Sweden and the USA, all cases diagnosed in the individual departments as congenital pseudarthrosis of the tibia were reviewed by the author. In 60 cases, all fulfilling the above mentioned definition, complete records and x-ray films dating from the time of the first treatment until treatment was completed or until 1970 were available. In 40 cases the patients were born between 1930 and 1960. In four of these cases the pseudarthrosis arose after an osteotomy. To obtain a more accurate definition

of the disease concept these four cases were not included and the present material thus consists of 36 patients

It was demonstrated in a previous paper (Andersen 1973) that on the basis of the primary x ray films a distinction may be made between four different radiological types of congenital tibial pseudarthrosis In the present material primary x ray films were available in 18 cases In the remaining cases x ray films from before the first treatment but after the fracture were available

Union of the pseudarthrosis is taken to mean all cases where the affected leg had been stable with radiological union for at least 24 months and where no re fracture later occurred in the observation period Union followed by re-fracture is taken to mean all cases where the affected leg had been stable with radiological union for at least 12 months but where a new fracture later followed The re-fractures occurred from 1½ to 8 years after the last operation on the pseudarthrosis For patients who at the time of the follow up had union of the pseudarthrosis and who had reached skeletal maturity the mean observation time for the union was 5 years (2 9 years) For patients with union who had not reached skeletal maturity the mean observation time was 7 years (3 9 years)

Table 1 The result in 1970 of the treatment in relation to radiological type of pseudarthrosis

Radiological type	Total no	No with union	No with union who have reached skeletal maturity	Average no of operations in cases with union
Dysplastic	14	6	4	6
Cystic	11	5	3	5
Sclerotic	8	5	3	4
Clubfoot	3	3	2	1
Total	36	19	12	

Table 2 The number of operative methods used in the treatment of 34 cases of congenital tibial pseudarthrosis

Type of operation	No
Diaphyseal fragmental reversal and intramedullary fixation	23
Dual onlay bone grafting	10
By pass graft	1
Translocation of the fibula	1
Telescoping	4
Intramedullary rodding and bone grafting	22
Simple bone grafting	29
Osteosynthesis and bone grafting	12
Supplementary operations	34
Others	7
	143

Table 3 The results of certain operative methods in the treatment of congenital tibial pseudarthrosis

Type of operation	Primary operations			Later operations			
	No	Mean age at operation	No with union	No	Mean age at operation	No with union	No with union after suppl op
Diaphyseal fragmental reversal and intramedullary fixation	5	40 months	0	18	60 months	2	5
Dual onlay bone grafting	0			10	74 months	1	0
Intramedullary rodding and bone grafting	4	28 months	0	16	69 months	4	0
Simple bone grafting	13	36 months	0	15	69 months	0	0
Osteosynthesis and bone grafting	2	19 months	0	8	80 months	1	1

The results of the treatment at the time of the follow-up in 1970 are listed in Table 1. As the prognosis for the clubfoot type is very favourable and quite different from the prognosis of the other types of pseudarthroses, these cases have been omitted in the following analyses.

The operative methods are listed in Table 2 Simple bone grafting means the insertion of a bone graft over the pseudarthrosis without any fixation of the graft with metal. No distinction is made between the various ways of placing the graft Supplementary operations means the application of additional bone grafts to the pseudarthrosis site (30 cases) or replacement of an intramedullary rod (4 cases), without any other operative intervention.

Union of the pseudarthrosis followed after two operations with diaphyseal fragmental reversal and intramedullary fixation, after two operations with intramedullary rodding and bone grafting, after one operation with dual onlay bone grafting, after one operation with telescoping and after one operation with a single bone graft fixated with screws The results of the individual operative procedures are given in Table 3 In no case was the primary operation followed by union The distribution of the different types of pseudarthroses submitted to the various operative methods varied but could not be related to the results The possible influence of the previous operations on the result of a single operation in relation to type of operative method is seen from Table 4 In order better to evaluate the

Table 4 The results of certain operative methods in relation to the previous operation in the same case of pseudarthrosis

Type of operation	Type of preceding operation					
	Diaphyseal fragmental reversal	Dual onlay bone graft	Telescoping	Intra-medullary rodding	Osteo-synth and bone graft	Simple bone graft
Diaphyseal fragmental reversal	9 (5)	0	0	5 (1)	0	3 (1)
Dual onlay bone graft	0	2 (2)	0	0	2 (2)	4 (1)
Telescoping	0	0	0	1 (1)	1 (1)	0
Intramedullary rodding and bone grafting	5 (1)	2	0	8 (2)	0	1
Osteosynth and bone grafting	1 (1)	3 (1)	0	0	3	1 (1)
Simple bone grafting	0	0	0	0	2	11 (4)

Figures indicate no of operations
Figures in brackets indicate no of operations followed by union, or by union and refracture, or by union after a supplementary operation

Table 5. The influence of resection of the pseudarthrosis on the result of the operative treatment

Radiological type of pseudarthrosis	Operation with resection of pseudarthrosis		Operation without resection of pseudarthrosis		
	No	Union	No	Union	
Dysplastic	28	3	14	0	$(P < 0.005)$
Cystic	22	0	7	0	$(P > 0.05)$
Sclerotic	13	2	8	1	$(P > 0.05)$

P value is calculated from the Four Fold Table Test

Table 6. The number of operations and the results in relation to the age of the patient at the time of operation

Age (years)	No *of operations*	No *followed by union*
0–3	45	0
3–6	53	4
6–9	20	5
9–12	10	3
12 15	8	3
15–18	2	0

tendency to union the number of operations followed by union as well as the number of operations followed by union after supplementary operations and operations followed by union and refracture are given

An accurate survey of the complications following the operative interventions is difficult to present because of the retrospective nature of the study In two cases serious infection followed operation one case after a diaphyseal fragmental reversal and intramedullary fixation and one case after simple bone grafting Following the diaphyseal fragmental reversal non union at the proximal osteotomy site followed the operation in six cases five of these being of the cystic type

No case operated upon without bone grafting was followed by union of the pseudarthrosis In 46 operations not including supplementary operations autologous bone was used in three operations followed by union and in six operations by union and refracture In 21 operations homologous bone was used, in three operations followed by union and refracture

Intramedullary fixation was not used in the treatment of *pseudarthroses of the* sclerotic type except for a few cases Among cases of the *dysplastic and* cystic types 11 were treated with intramedullary rodding and *fixation of the* tarsus One operation was followed by union and five operations by *migration or breakage* of the intramedullary pin In 26 operations intramedullary rodding without fixation of the tarsus was used *in* two operations followed by union and in 12 by migration of the intramedullary *pin*

Table 7. Results of operative treatment in relation to the total number of operations

Total no. of operative interventions	No. of pseudarthroses	Pseudarthroses with union	Amputations
1–3	12	3	8
4–6	12	8	4
7–9	7	5	2

Table 8. Number of operations and their results in cases treated in Scandinavia and in USA.

	No. of hospitals	No. of pseudarthr.	No. of ord. op.	No. of suppl. op.	Pseudarthr. with union
Scandinavia	7	11	33	2	1
USA	3	22	72	32	15

The effect of resection of the pseudarthrosis in operations other than supplementary ones is seen in Table 5. The results of all operations including supplementary operations in relation to age is shown in Table 6. Two cases of the dysplastic type had no operative treatment but were immobilised in plaster and brace and finally amputated at the age of 7 and 9 years, respectively. The remaining 31 cases were operated on from one to nine times each. The rate of union in relation to number of operative interventions is shown in Table 7. The distribution of the cases in relation to nationality of treating department and the result hereof is shown in Table 8.

DISCUSSION

Analysing the results of operative treatment of congenital pseudarthrosis of the tibia one comes up against several difficulties. Owing to the rare occurrence of the condition even large clinics can hardly reach a double figure within a reasonable period. This being the case it seems acceptable to evaluate this material a little closer and involve all operative interventions in the analysis.

Several authors have classified congenital tibial pseudarthrosis by type (Camurati 1930, Fevre 1954, Guillemmet & Ricard 1958, Hardinge 1972, Sage 1971) but no one has attempted an actual analysis of incidence and prognosis of the individual types, although the question has been raised (Fevre 1954, Nicoll 1969). The radiological classification used in the present analysis (Andersen 1973) is based upon the

radiological findings in the pre pseudarthrosis stage Although x ray films from prior to or immediately after the fracture were available in only 18 cases all cases could be classified on the basis of the x ray films

From Table I it is apparent that the prognosis of congenital pseudarthrosis of the tibia depends upon its radiological type By far the best results were found after treatment of pseudarthroses of the *clubfoot* type in which union was obtained after fewer operations and even by plaster cast alone This was not previously considered possible (Boyd & Sage 1958) However in a large material Hardinge (1972) found union in three per cent after immobilization in plaster as the only treatment As the prognosis for the clubfoot type differed essentially from the other types of pseudarthroses these three cases were not considered in the following analysis

To-day it is not possible to decide with certainty which type of operation should be selected for each individual case of pseudarthrosis of the tibia However it seems beyond doubt that simple bone grafting affords a poorer result than other methods (Hardinge 1972 McBryde & Stelling 1972 Sofield 1971) Operation by dual onlay bone grafting and by intramedullary rodding affords good results according to several authors (Apoil 1970 Sage 1971 Sofield 1971 Van Nes 1966) In the present material the results of the various operative methods showed no significant differences when all primary and supplementary operations were excluded Considering all operations the results after the diaphyseal fragmental reversal and intramedullary fixation might be better than after any other operation but the difference is not statistically significant ($P > 0\ 20$) Lastly the diaphyseal fragmental reversal operation carries an appreciable number of complications the most important being non union at the proximal osteotomy site However new operative methods (d Aubigne et al 1970 Wall & Refior 1970) as well as prophylactic operations (Lloyd Roberts & Shaw 1969) could not be evaluated due to the retrospective nature of the analysis

Considering the single elements in the operative procedures bone grafting is a *sine qua non* in any operation for congenital pseudarthrosis of the tibia In most cases grafting was done by autologous bone but there was no difference between the results after autologous and after homologous bone grafting ($P > 0\ 20$) considering all other factors equal

Regarding the fixation of the pseudarthrosis there was *no* statistically significant difference between the results *after plating* and after intra

medullary rodding. Probably there was a more pronounced tendency towards refracturing after plating. Of four pseudarthroses of the sclerotic type operated upon with intramedullary fixation there were no refractures, whereas there was one refracture after three sclerotic pseudarthroses operated upon with dual onlay bone grafting. The refractures after plating always occurred at the distal end of the plate. Among all operations there were 11 refractures, four of which occurred after dual onlay bone grafting and one after plating and grafting, whereas only one occurred after intramedullary rodding. Whether or not intramedullary rodding with fixation of the tarsus gave a better fixation could not be shown ($P > 0.05$).

Some authors have recommended lengthening of the Achilles tendon or amputation of the forefoot in order to improve the chance of union in the pseudarthrosis. In the present analysis only two amputations of the forefoot were done and only one lengthening of the Achilles tendon. As resection of the pseudarthrosis may mimic the same effect the results after operations with and without resection of the pseudarthrosis were considered. For pseudarthroses of the dysplastic type resection of the pseudarthrosis gave a significantly better result ($P < 0.005$), whereas there were no differences for the cystic and sclerotic types of pseudarthrosis.

Previously it has been claimed that operative treatment of congenital tibial pseudarthrosis should not be started until after the age of 4 to 6 years. Now several authors emphasize the advantages of an early operation, and also of a rapid re-operation if the primary operation does not lead to union (McBryde & Stelling 1972, Sage 1971, Sofield 1971, Sulamaa & Vilkki 1963) According to Hardinge (1972), however, "long term union" is not obtained by any operation before the age of 33 months. As seen from Table 6 one might get the impression that age is a factor of importance. This is probably not correct and as seen from Table 7 the total number of operative interventions presumably is of much more importance

The influence of a previous operation is difficult to evaluate. From Table 4 one might get the impression that the continuous use of the same operative procedure may better the chance of union. Obviously this impression is not statistically valid. From the analysis one might conclude that so far there seems to be no operative method of choice, as long as one uses a method which gives a solid fixation of the pseudarthrosis and includes transplantation of bone.

The present material is selected in that not all cases treated in the

different hospitals are included From Table 8 it is apparent that the treatment in American and Scandinavian departments differs in respect to the use of supplementary bone grafting and it is obvious that the latter procedure favours a good result

On the basis of the analysis one might conclude that there so far seems to be no operative method of choice in the treatment of congenital tibial pseudarthrosis The prognosis is dependent on the type of pseudarthrosis The result of the operation is favoured by solid fixation resection of the pseudarthrosis and abundant bone grafting Experience in treating cases of this type seems to be of equal importance

SUMMARY

A total of 36 cases of congenital tibial pseudarthrosis born 1930–1960 and treated in American and Scandinavian orthopaedic hospitals have been analysed There seems to be no operative method of choice The prognosis depends on the radiological type Factors favouring a good result from the operation are solid fixation resection of the pseud arthrosis and abundant bone grafting Experience in treating cases of this type seems to be of equal importance

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THE RESULTS OF EXTRA ARTICULAR SUBTALAR ARTHRODESIS ACCORDING TO THE GREEN GRICE METHOD IN CEREBRAL PALSY

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Foot deformities reduce the possibility of proper gait training in children with cerebral palsy, and therefore early correction of these deformities is advisable Unfortunately many cases are first seen by the orthopaedic surgeon when the deformity is pronounced as was the case in many patients in the present material

Green & Grice presented in 1950, in a preliminary report, their method of extra articular subtalar arthrodesis for cases of paralytic flat foot Later the method was also tried for correction of valgus deformity in cerebral palsy often in conjunction with lengthening of the Achilles tendon to correct the concomitant equinous deformity Malvarez (1957) Baker & Dodelin (1958), Picard & Mimran (1961), Stagnara & Desbrosses (1961) Baker & Hill (1964), Chigot & Sananes (1965) Kenig (1966) and many others have achieved relatively good results with this method in cerebral palsy, but have also shown that recurrences and complications are not uncommon Keats (1970), however demonstrated excellent results in a large series

This method has been in use at the University Hospital of Uppsala, but since the results have not been fully satisfactory, it is of interest to analyse the causes of the failures

MATERIAL

The present series reviews 27 feet operated upon on 16 children with cerebral palsy The age at operation varied between 3 and 12 years with an average of 6 years 10 months Eight cases had neurological di or hemiplegia without hypotonia and

four had slight to moderate hypotonia, one child had a post traumatic spastic tetraplegia and the remaining three had a complex neurological status with spastic paresis in the lower extremities The main indication for operation was the dominant valgus deformity often in combination with a concomitant equinus deformity, resulting in balance and gait difficulties In many cases an abduction deformity of the forefoot was also present

METHODS

Subtalar arthrodesis was performed according to the method described by Grice in 1952, and for the present series the operations were performed by seven different surgeons In 21 operations an autologous tibial bone graft was used, in three of these combined with a heterologous, de fatted and de proteinized transplant (Kieler Knochen) In six operations only heterologous transplants were used Lengthening of the Achilles tendon had either been performed previously or was done during the same procedure in 19 cases The period of postoperative plaster fixation was about 12 weeks

The present review was undertaken 1 to 8 years after operation, the average being 3 years and 3 months In the survey the following factors were noted in particular—the clinical stability at the arthrodesis, the movement in the ankle joint and the function of the foot during weightbearing

Radiological examination of the feet with and without weightbearing was also made in order to evaluate the healing at the arthrodesis, the position of the talus relative to the tibia fibula and calcaneus and finally the stability of the foot in weightbearing Besides antero posterior and lateral projections oblique projections were used to visualize the tarsal sinus for study of the consolidation of the bone transplant If in doubt tomograms were performed

RESULTS

Radiologic results

The arthrodesis was established in 18 of the 27 feet in the study Of the nine cases of non union one had healed primarily but the transplant fractured later (Figure 1) and the reoperation was unsuccessful In two cases the transplant united only to the talus or the calcaneus, and as the transplant remained intact the functional result was that of an arthrorisis In the remaining six cases we found that no union had occurred and that the transplant was either fully or partially absorbed In two of these six cases heterologous transplants had been used as also in the two cases above which developed arthrorisis

All the cases with non-union were in the age range of 3 7 years at operation

Figure 1 Lateral projection of the subtalar joint The bone transplant is fractured and the talus has slipped forward and is in an abnormal rather vertical position



Table 1 Comparison between clinical and roentgenological findings

Clinical findings	Roentgenological findings		
	Union	Arthrorisis	Non union (Graft resorbed)
Fully corrected and with subtalar stability	11	1	–
Corrected equinus or valgus but residual abduction < 15° Subtalar stability	3	1	–
Corrected equinus valgus insignificant or none at all Abduction > 15° Subtalar stability	2	–	–
No equinus or valgus Abduction > 15° without weightbearing. Subtalar stability	2	–	–
Subtalar instability	–	–	6
Insignificant varus No other deformity Subtalar mobility Improved gait	–	–	1
Total	18	2	7

Clinical results (Table 1)

1) Subtalar stability and full correction of the deformity in 12 of the operated feet.
2) Subtalar stability and full correction of the valgus and equinus deformity but a residual abduction deformity of the forefoot of 15° maximum in four of the operated feet.
3) Subtalar stability, none or insignificant valgus or equinus deformity of the foot but a residual abduction deformity of the forefoot of more than 15° in two operated feet.
4) Subtalar stability and residual abduction in two feet of a patient with a post-traumatic spasticity and tetraplegia whose condition had progressed to a stage not allowing weight-bearing.
5) Subtalar mobility and recurrence of the deformity in six cases.
6) Subtalar mobility, insignificant varus in weightbearing and despite non-union a functional improvement in one case.

Summarizing, the clinical assessment showed full or satisfactory correction in 16 cases, recurrence in six, and unsatisfactory results consisting mainly of residual abduction of the forefoot in two. Finally in two cases the results were functionally indeterminable and in one case there was functional improvement despite non-union of the arthrodesis.

DISCUSSION

The reasons for unsatisfactory results, as mentioned in the literature, are non-union of the arthrodesis, over- or undercorrection of the valgus deformity, residual abduction deformity of the forefoot as sequelae to hypermobility or dysplasia of the bones and the small joints in the forefoot, and incomplete correction of the muscular imbalance.

The best results have been reported by Keats (1970) in whose series with 112 cerebral palsy cases not a single case of non-union was reported. Lahdenranta & Pylkkanen (1972) reported non-union in approx. 10 per cent of cases with valgus deformity and approx. 35 per cent with varus deformity in a material composed mainly of paralytic foot deformities. Zachariae (1963) reported non-union in 25 per cent in a series with paralytic flat feet, and Kenig (1966) reported a 27 per cent recurrence in cases af spastic deformities. In our present series union could be demonstrated in only 18 of 27 arthrodesis operations.

There is no doubt that non-union is often due to faulty technique

Keats (1970) and Baumann (1970) point out that "the key to success" is that the head of the talus is properly supported by the sustentaculum

Reposition can be facilitated by incising the capsule and ligaments of the talo-navicular joint, and stabilization can be improved by a screw, Kirschner wire (Grice 1959) or staples Judging from the early postoperative radiographs incomplete reposition does not seem to be the cause of non-union in our series

A suitable length of bone transplant and correct insertion is a necessary prerequisite to union, otherwise a dislocation of the bone graft may occur, as in one of our cases The operations in our study had been performed by seven different surgeons This can hardly be considered satisfactory The preoperative assessment and the operation of neuro-orthopaedic cases ought to be performed by an experienced surgeon specializing in this field

Chigot & Sananes (1965) have pointed out that autologous tibia grafts often do not have the stability to withstand the forces generated by the peroneal muscles in spastic flatfeet According to their report the use of fibula grafts gave significantly better results than tibia grafts Keats (1970) has used mainly homologous grafts and his success may depend on the better stability of such grafts

Fracture of the graft has been previously reported not only in cases of extra articular arthrodesis according to Grice but also in cases treated by Batchelor's method (Brown 1968, Seymor & Evans 1968) Internal fixation with a screw or staples could provide a suitable preventive measure In our series heterologous bone grafts were used in six cases In two of these the consolidation was proportionately delayed, in two cases we found pseudarthrosis 3 5 and 4 years after operation, with the final result an arthrorisis instead of an arthrodesis In the remaining two cases the bone grafts were almost completely resorbed Thus heterologous bone grafts are not suitable for these operations

In the cases with good union of the arthrodesis we found no overcorrection of the preoperative valgus deformity, neither undercorrection but correction of the preoperative abduction deformity of the forefoot has not always occurred In five feet the abduction deformity was corrected in another five feet the abduction deformity had decreased substantially to less than 15°, and in four feet the residual abduction deformity remained between 15–30° giving unsatisfactory weightbearing and some instability of the foot

Thus to some degree, specially in younger children, one can achieve satisfactory correction of the abduction deformity by correcting the

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4) Subtalar stability and residual abduction in two feet of a patient with a post-traumatic spasticity and tetraplegia whose condition had progressed to a stage not allowing weight-bearing
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6) Subtalar mobility, insignificant varus in weightbearing and despite non-union a functional improvement in one case

Summarizing, the clinical assessment showed full or satisfactory correction in 16 cases, recurrence in six, and unsatisfactory results consisting mainly of residual abduction of the *forefoot* in two Finally in two cases the results were functionally *indeterminable and in one* case there was functional improvement *despite* non-union of the arthrodesis

DISCUSSION

The reasons for unsatisfactory results, as mentioned in the literature, are non-union of the arthrodesis, over- or undercorrection of the valgus deformity, residual abduction deformity of the forefoot as sequelae to hypermobility or dysplasia of the bones and the small joints in the forefoot, and incomplete correction of the muscular imbalance

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There is no doubt that non-union is often due to faulty technique

suitable bone grafts and internal fixation, and by careful selection of the patients

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valgus deformity, but in older children with more pronounced preoperative abduction deformity a triple arthrodesis seems to be a better alternative as already pointed out by Grice in 1959. An analysis of the abduction deformity including radiological examination ought to be undertaken before the operative procedure is decided upon.

The analysis of our unsuccessful cases shows that the major cause was non-union. This was related to the fact that heterologous grafts were unsuitable for these operations and that autologous tibia grafts in the younger children lacked the required strength. In the future we intend to use a fibula graft, and also to use internal fixation—either screw or staple—to ensure a proper fixation and to minimize the risk of fracture of the graft. Only experienced surgeons will be allowed to handle the neuro-orthopaedic cases. When healing occurs this method gives good or satisfactory clinical results. As it ought to be possible to improve the frequency of healing taking into account the suggestions given above, we will keep to the extra-articular subtalar arthrodesis in carefully selected cases. However, in cases with a more pronounced abduction deformity other methods ought to be applied, alternatively complementary surgical corrections performed.

CONCLUSIONS

The main reason for our failures was non-union. This seems to have been caused mainly by the use of heterologous or osteoporotic autologous grafts and less by faults in the operative technique. Better autologous grafts, e.g. fibula, ought to give a higher frequency of union. Complementary internal fixation with a screw or staples may be needed. If valgus deformity is combined with severe abduction deformity of the *forefoot satisfactory correction is not* always possible with extra-articular arthrodesis. Thus complementary surgical correction of abduction deformity may be necessary. Alternatively a triple arthrodesis can be used.

SUMMARY

Results from 27 extra-articular subtalar arthrodeses in 16 children with spastic planovalgus or equinovalgus foot deformities are presented. The clinical results are good in cases where union has occurred, except in cases with a pronounced preoperative abduction deformity. The main cause of failure is non-union. The clinical results and the frequency of union ought to be greatly improved by the use of more

vey X rays were either normal or showed dysplasia The arthrographies were all normal except two which showed delayed ossification

The 12 cases in subgroup "B II" are the classical luxation cases. The indications for arthrography are the same as in subgroup "A II"

THE IMPORTANCE OF ANALYSIS OF SKELETAL DEFORMITIES IN CONGENITAL CLUBFEET FOR ADEQUATE SURGICAL TREATMENT

Ake Hjelmstedt (Uppsala, Sweden)

The main skeletal deformities recorded in congenital clubfeet are medial and plantar dislocation of the navicular bone, medial and plantar deviation of the talar neck and head flattening of the trochlea, medial bowing of the calcaneus and medial subluxation or deviation of the cuboid Many dissection studies on foetuses and the newborn have shown that the skeletal deformities vary from being rather slight to being very extreme In the latter cases conservative treatment or soft tissue operations are insufficient corrective methods



Figure 1 a Simultaneous arthrography of the tibio talar and talo navicular joints in a 2½ year old boy Lateral view of the right foot Normal arthrogram



Figure 1 b Same case as in 1 a Arthrogram of a congenital clubfoot (left foot) Note the slight flattening of the trochlea and the small recesses of the ankle joint There is plantar deviation in the talo navicular joint which because of its medial deviation has an oval appearance

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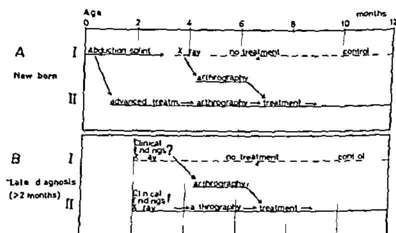
ARTHROGRAPHIES OF DYSPLASTIC AND CONGENITALLY DISLOCATED HIPS DURING THE FIRST YEARS OF LIFE

Bo Almby & Torsten Lonnerholm (Uppsala, Sweden)

During the period 1972–1974 a *total of 40* patients, 2 months to 2 years old with dysplasia and/or dislocatable hip(s) *were* examined using arthrography (in general bilateral examinations)

All hip joints were punctured 1 *cm medial* to the femoral artery without any complications

The *material* was classified (see Table)



The 15 children in group (A) had dislocatable hip(s) at birth and were treated with an abduction splint for 3 months and then examined with survey X rays

In subgroup (A I) all 10 children about 3 months old had clinically normal hips but the survey X rays showed dysplasia The arthrographies showed only delayed ossification of acetabulum and femoral head and no anatomical defects

The five cases in subgroup (A II) had in spite of regular treatment dislocatable hip(s) at 3 months of age Arthrography was necessary to select cases for operation and to find the best position for the femoral head in the joint

Group (B) consisted of 25 cases All children were at least 2 months old when a clinical diagnosis of hip disorder was made

In subgroup (B I) all 13 children had solitaire limitation of abduction The sur-

muscle balance by soft tissue procedures is sufficient In cases with extreme deformity soft tissue procedures should be supplemented by correction osteotomies through the talar neck and the calcaneus

ARTHROGRAPHIC ANALYSIS OF THE CONGENITAL CLUBFOOT

Bo Sahlstedt (Uppsala, Sweden)

In congenital clubfoot the principal skeletal changes are localized in the talus, the calcaneus and the navicular The trochlea tali is flattened and the head and the neck of the talus have a plantar and medial deviation There is often a medial and plantar luxation of the navicular bone

Through simultaneous arthrography of the tibio talar and talo navicular joints it is possible, even in small children and infants to judge the contours of the talus and measure the plantar and medial deviation of its head and neck. The navicular luxation can be demonstrated through a secondary flattening of the navicular facet of the head of the talus Arthrography also gives important information about the joint recesses This anatomical demonstration is a good guide in the selection of operative procedures The method requires precise and standardized projections the most important being the lateral view of the trochlea and the frontal view of the foot Fluoroscopic control facilitates the positioning of the deformed foot and makes it possible to study the mobility of the ankle

Puncture of the joints is relatively easy Talo navicular joint puncture is most easily accomplished with a dorsal approach and that of the tibio-talar joint from an antero medial direction

94 arthrographies have been performed on congenital clubfeet and 20 on secondary clubfeet without complications Of the congenital clubfeet investigated, 40 per cent had a pronounced medial deviation of the head of the talus and 25 per cent a pronounced plantar deviation (Figures 1 and 2 pages 953–954)

ARTHROGRAPHY IN DIAGNOSIS OF EARLY LOOSENING OF A HIP PROSTHESIS

G Hallin & L E Lorelius (Uppsala Sweden)

Arthrography has been used to detect early loosening of a hip prosthesis We have used the technique described by Salvati et al (*J Bone Jt Surg* 1971 No 4)

In 18 patients with 16 cups and 18 shafts the arthrographic results were compared with findings at reoperation One cup and seven shafts loose at reoperation were not revealed by arthrography These false negative arthrographies were more frequent when the cement was mixed with barium Three cups and one shaft were diagnosed as loose at arthrography but this could not be verified at reoperation These false positive arthrographies were more frequent with radiolucent cement We have found that arthrography in diagnosing early loosening of a hip prosthesis is for the moment not a very reliable investigation

ANATOMICAL PHYSIOLOGICAL AND ARTHROGRAPHIC STUDIES ON BURSA GASTROCNEMIO SEMIMEMBRANOSA

P G Lindgren (Uppsala Sweden)

On autopsy material 116 knee joints were examined by arthrography and dissection The frequency of bursa gastrocnemio semimembranosa was almost the



Figure 2 a Same case as in Figure 1 Normal arthrogram of the right foot with the talus seen from above



Figure 2 b Same case Arthrogram of the patient s congenital clubfoot (left foot) The deformed talus is seen from above Note the pronounced medial deviation of the navicular facet of the head

In cases where conservative treatment has failed operative procedures are indicated As a guide to the choice to be made between the different procedures an analysis of the skeletal deformity by arthrography has proved to be of great value In clubfeet with slight to moderate talar dysplasia and with only slight deformity of the talo navicular joint reposition of the navicular bone and restoration of the

THE DIAGNOSTIC SIGNIFICANCE OF ARTHROGRAPHY IN ACUTE LESIONS OF THE JOINT OF THE FOOT

[illegible] Vilhelmsen & Holger Glastrup (Stege, Denmark)

[illegible] of the foot [illegible] complica-[illegible]tions having been observed The technique is [illegible] [illegible]cluded that arthrography of the joint of the foot is an important method of examination which *should be applied in all cases* where a justified suspicion of a lesion of the capsule or ligament of the joint of the foot is present It is stated that during the past two [illegible] drawn to the fact that a *lesion of the subtalar ligaments* [illegible] a great prog-[illegible] also present [illegible]

THE DIAGNOSTIC VALUE OF ACUTE ANKLE ARTHROGRAPHY ESTIMATED FROM THE FINDINGS AT OPERATIONS

F Lindholmer N Foged O Gimrerup & I Th Jensen (Aalborg, Denmark)

In a retrospective survey we have compared 116 ankle arthrographies with the operative diagnoses In this way it was found that ankle arthrography has a satisfactory diagnostic value

For the different arthrographic signs and combinations of these the diagnostic percentages—sensitivity specificity predictive value of a positive criterion and predictive value of a negative criterion—have been calculated

As to the rupture of the anterior talo fibular ligament there were only three to five false positive diagnoses (depending on the criterion used) out of 100 The negative diagnostic value has not been examined for this ligament, since only patients with a pathologic arthrography have been operated on

As to the rupture of the calcaneo fibular ligament we find a lower, but still satisfactory diagnostic value The best criterion for rupture of this ligament is found to be lateral contrast escape defined by escaped contrast behind the middle of the lateral malleolus in the lateral projection By this criterion the diagnostic percentages were 65 to 76 per cent From the point of view that the anterior talo fibular ligament should be sutured it is of less practical value to diagnose rupture of the calcaneo fibular ligament since the anterior talo fibular ligament is always torn in cases of rupture of the calcaneo fibular ligament

SURGICAL TREATMENT OF OSTEOSARCOMA

Ulf Nilsonne (Stockholm Sweden)

The surgical management of osteosarcoma almost invariably includes amputation Previously such amputations were often performed with a somewhat conservative approach providing what was macroscopically deemed to be a sufficient margin to the tumour site More recently a more radical approach has been adopted, aimed at total resection of the skeletal structure harbouring the tumour site In *osteosarcoma of the femur* for instance this involves exarticulation at the hip joint In current international practice treatment consists of preoperative irradia

same as in a series of unselected routine arthrographies It is higher in elderly people

The dissection studies showed that a valve mechanism in the connection between the knee joint and bursa gastrocnemio semimembranosa is present Pressure measurements have been carried out in the knee joint and bursa gastrocnemio semimembranosa simultaneously and the findings verify the possibility of this valve mechanism

CORRELATION BETWEEN ARTHROGRAPHIC AND OPERATIVE FINDINGS IN RUPTURE OF KNEE DISCS

Per Edvardsen & Bjorn Samstad (Trondheim Norway)

From 1953 1973 994 patients were treated for rupture of the knee disc 768 of these patients were investigated with arthrography using various techniques but with a double contrast method from 1962

The majority of cases of both sexes were in the third decade, the number of male to female patients was about 4 1 The relation between rupture of medial to that of lateral disc differed between the two sexes being about 4 1 in men and 2 1 in women Further a slight sex difference was found as regards side affected the right knee predominating in men and the left in women

In 571 patients rupture was proved quite positively out of these cases 563 were operated upon In this group one false positive case was found In another group of 123 patients having probably positive arthrograms 108 were operated In this group two false positive diagnoses were observed In a third group consisting of 72 patients with negative radiological findings 28 were operated on because of the clinical signs and a rupture was revealed in all cases

Out of the total number of arthrograms of the knee menisci a false positive result was obtained in 0 3 per cent whereas a false negative one was obtained in 4 0 per cent

LOCKING OF THE KNEE JOINT CAUSED BY EXTRAMENISCAL LESIONS

Henrik Schmidt (Nykobing Falster Denmark)

The main reasons for carrying out arthrography of the knee joint are lesions of the menisci As mentioned by Stable in 1972 many other diseases in the knee joint are easily diagnosed on double contrast arthrography Some of these may cause locking of the knee with symptoms quite similar to those of the meniscal rupture

Such diseases are foreign cartilaginous bodies in the femoropatellar joint chondromalacia of the patella hypertrophy of the fat body of Hoffa and hypertrophy of the synovial membrane

Examples of each category are found in a material of 300 double contrast arthrographies made by the author since November 1971 In each case the disease in question has been diagnosed on the arthrograms and was found to be the only (though uncommon) cause of locking

The technique used is a modification of the method of Van de Berg & Crevecoeur (1951) with special attention to the axial patella position of Knutsson & Wiberg

Each example illustrates the widened use of knee joint arthrography

THE DIAGNOSTIC SIGNIFICANCE OF ARTHROGRAPHY IN ACUTE LESIONS OF THE JOINT OF THE FOOT

Gudmund Vilhelmsen & Holger Glastrup (Stege, Denmark)

An experience of 13 years of working with arthrography of the joint of the foot is presented. More than 200 examinations have been made without any complications having been observed. The technique is described, and it is concluded that arthrography of the joint of the foot is an important method of examination which should be applied in all cases, where a justified suspicion of a lesion of the capsule or ligament of the joint of the foot is present. It is stated that during the past two years attention has been drawn to the fact that a lesion of the subtalar ligaments is presumably being found rather often, and that these lesions have a great prognostic significance. As they cannot be visualized by arthrography they also present diagnostic and therapeutic problems

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As to the rupture of the anterior talo-fibular ligament there were only three to five false positive diagnoses (depending on the criterion used) out of 100 The negative diagnostic value has not been examined for this ligament, since only patients with a pathologic arthrography have been operated on

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tion followed by radical amputation in the absence of metastases after six months. The possibilities of local resection in cases of osteosarcoma will also be discussed at the symposium.

In view of the possible virogenetic nature of osteosarcoma, combined treatment has been started with an antiviral agent in the form of Interferon, the preliminary experiences of this therapy will be reported. In addition, treatment of solitary metastases, specifically in the lungs, by means of lobectomy or pulmonectomy will be discussed.

IRRADIATION OF OSTEOGENIC SARCOMA

Lars A. Baldetorp (Lund, Sweden)

Osteogenic sarcoma has a relatively low radio sensibility. Its devitalization requires doses between 7000–10000 rads over 7–10 weeks. High voltage irradiation however, now enables adequate doses to the tumour without objectionable side effects in the skin or surrounding healthy tissues.

A 5 year survival is attainable in 11–12 per cent of patients treated solely with irradiation (Sweetnam et al. 1971, Friedman et al. 1972). Tumours of Grade I are best suited for irradiation, which is primarily recommended for osteogenic sarcoma in the arms in order to maintain their important function.

Cade states that preoperative irradiation, with amputation after 4–6 months gives a survival rate comparable with the best results of surgery (Lee et al. 1967, Sweetnam et al. 1971, Allen et al. 1973). Adequate tumour doses give acceptable protection 3–6 months prior to selective ablation, and patients showing general malignancy can be spared amputation.

Irradiation with fast neutrons can perhaps increase our possibilities of curing osteogenic sarcoma without ablation. Irradiation combined with chemical therapy is being tried but our experience is limited. Prophylactic irradiation of microscopic metastases in the lungs is being done but the results are difficult to evaluate (van der Werf Messing 1973, Caldwell 1973).

EXOGENOUS INTERFERON THERAPY OF OSTEOGENIC SARCOMA

Hans Strander, Kari Cantell, Per A. Jakobsson, Ulf Nilsonne & Gunnar Soderberg (Stockholm, Sweden and Helsinki, Finland)

Conventional treatment of osteogenic sarcoma consists of amputation with or without preoperative irradiation. Prognosis is poor: 20 per cent survive 5 years. New therapeutic efforts are urgently required.

Animal experiments have shown that the anti viral agent interferon enhances the cytotoxic ability of sensitized lymphocytes to kill tumour cells. It also exposes surface antigen on tumour cells and inhibits the growth of malignant cells in various systems *in vitro* and *in vivo*. A method was developed for the large scale production of human leukocyte interferon. This type of preparation was found suitable for therapeutic trials in man and also exerted growth inhibitory effects on human osteogenic sarcoma cells *in vitro*. It has now been used for the last two years as adjuvant therapy of osteogenic sarcoma.

During the last 2 year period nine consecutive patients with osteogenic sarcoma were given exogenous interferon together with conventional therapy at the Karolin

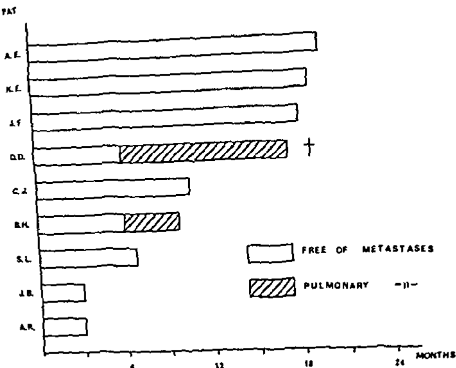


Figure 1 Length of therapy and metastases in individual patients

ska Hospital The interferon was given i m in a dose of 2.5 × 10^6 standard interferon units three times weekly Age on admission varied from 9 to 29 years One patient had fibroblastic-osteoblastic, two patients had fibroblastic, one patient had chondroblastic and five patients had osteoblastic sarcoma One tumor was situated in the humerus, two were situated in the femur, five in the tibia and one was localized in the fibula. No toxic effects of the interferon therapy were observed Figure 1 shows that seven of the nine patients treated so far are free from detectable pulmonary metastases The result is encouraging and the potentiality of exogenous interferon therapy should be further evaluated

CELLULAR IMMUNITY AGAINST TUMOR ASSOCIATED ANTIGENS IN HUMANS LYMPHOCYTE STIMULATION AND SKIN REACTION

Farkas Vanky (Stockholm, Sweden)

3M KCl extracts prepared from human tumors (14 sarcoma, two astrocytoma, three nephroblastoma Wilm s and one melanoma) and from non malignant tissues (nine muscle three skin two cartilage, one kidney, two brain and one bone marrow) have been used to stimulate autologous and allogenic lymphocytes and as antigen in autologous skin tests The results of the lymphocyte stimulation by autologous tumor biopsy cells and their KCl extracts were concordant Moreover, these

in vitro results correlated well with the in vivo immune reactivity indicated by skin tests Tumor cell suspensions were weak allogenic stimulators and KCl extracts were stimulatory only after presensitization When tumor cells and their KCl preparation were used in autologous and 11 allogenic tests the degree of autologous stimulation with tumor cells was as high as the highest allogenic one and the KCl extract stimulated with similar strength the autologous lymphocytes The results strengthen the validity of the lymphocyte stimulation test as an assay for a tumor specific reaction

CELLULAR IMMUNITY AGAINST SARCOMA ASSOCIATED ANTIGENS IN HUMANS LYMPHOCYTE STIMULATION AND SKIN REACTIONS

Farkas Vanky Ulf Nilsonne & Eva Klein (Stockholm Sweden)

The existence of a specific antitumor immunity demonstrated by various in vitro assays is by now well documented The dilemma is not to demonstrate such reactions but to determine the relevance, if any, of the in vitro findings to the complex in vivo situation We have tried to remedy this deficiency by using the same antigen preparation both in vitro and in vivo

The lymphocyte stimulation (LS) test was used in the search for tumor specific cellular reactivity in humans There is good reason to believe that lymphocyte stimulation by autologous tumor cells represents a tumor specific phenomenon Such observations as the lack of stimulation obtained by non malignant cells and the dose dependence of the lymphocyte tumor cell interaction support this idea Soluble antigens prepared with hypertonic KCl from tumor and non malignant tissue biopsy cells were used successfully as stimulators and parallel tests with cells and extracts gave corresponding results in 26 out of 28 cases

Thirty one patients were tested for their ability to develop a delayed type hypersensitivity reaction to the reinjected KCl extracts of autologous tumor and non malignant cells Reaction against the tumor extract occurred in 15 skin tests

The in vitro results of the LS test correlated well with the in vivo cellular immune reactivity measured as delayed type hypersensitivity in 25 out of 31 cases

Lymphocyte stimulation in vitro with cells or cell extracts may thus reflect in vivo events of cellular immunity and seems to correlate with the clinical stage of the malignant disease

BONE SCINTIGRAPHY IN PRIMARY BONE TUMOURS

Jan Heerfordt & Ilse Vistisen (Copenhagen Denmark)

The Copenhagen centre for sarcoma treatment receives an increasing number of patients from the eastern half of Denmark and from Greenland It comprises three departments the orthopaedic pathology and radiotherapy departments working in close cooperation

Bone scintigraphy with technetium polyphosphate and or radioactive fluorine was introduced at the centre 1½ years ago An assessment of the clinical usefulness of this sensitive but unspecific method has been attempted and it has been found that in many cases bone scintigraphy will not add to the information regarding diagnosis and treatment however, in three situations we find the method valuable 1) As a simple and rapid investigation for example easily performed in the out



Figure 1. Fibrosarcoma in the right iliac bone. Fluorine scan shows normal sacroiliac joints. Hemipelvectomy seemingly radical.



Figure 2. Osteogenic sarcoma in the right iliac bone. Fluorine scan shows affection of the right sacroiliac joint. Hemipelvectomy was macroscopically radical, but recurrence soon occurred.

patient department scintigraphy can indicate whether an osseous process is likely to be benign or malignant 2) In a soft tissue sarcoma close to bone scintigraphy can indicate whether radiologically normal bone is invaded by tumour tissue or not 3) In patients with sarcoma of the pelvis scintigraphic examination of the os *sacrum and the sacro iliac joints may help regarding the indication and effective ness of hemipelvectomy (Figures 1 and 2)

Technetium polyphosphate in other situations a valuable agent for bone scintig raphy has in our hands been less reliable than radioactive fluorine especially in *this group of patients false positive scintigraphies are seen most frequently due* to uptake of technetium polyphosphate in tumorous or non tumorous soft tissue

BONE TUMOURS AND INTRAMEDULLARY PRESSURE

P H Widmark (Malmo, Sweden)

The intramedullary pressure was measured in 11 cases with metastatic or primary bone tumour

In chondrosarcoma giant cell tumours and metastatic hypernephroma the pres sure was increased

Great variations in the pressure occur in prophylactic intramedullary nailing

RESECTION TREATMENT OF PRIMARY BONE TUMOURS

E V S Koskinen (Helsinki Finland)

In resection treatment of destructive bone tumours the defect may be substituted with an autogenous or homologous bone transplant or an endoprosthesis in which case mobility of the joint may be retained The alternative is to replace the defect with grafted bone combined with arthrodesis Modern methods of osteosynthesis are well suited to regeneration of the transplants and to bony union at the juncture which takes a comparatively long time in massive bone transplants This resection *en bloc* is indicated in carefully selected cases and depends on the behaviour of the tumour

In a series of 130 patients subjected to resection of bone tumour benign tumours were found in 78 cases semi malignant tumours in 21 cases and malignant tumours in 31 Giant cell tumours and fibrous dysplasia were each involved in about one quarter of the cases the other cases included aneurysmal bone cyst chondroma chondrosarcoma fibrosarcoma and osteosarcoma

In the subseries of 52 malignant or aggressive tumours a successful result ensued in 19 out of 21 giant cell tumour cases there was one recurrence which left the patient paraplegic with metastases An extremity threatened by a cartilaginous tumour was saved in 21 out of 23 cases (including seven reoperations four of them for recurrence) One extremity was amputated and one patient *(recurrence)* was lost Seven out of nine extremities with other sarcomas were saved whereas there was one amputation and one postoperative death



Figure 1 a Chondrosarcoma of the left distal end of the radius Angiography showed early tumour stain

b Treatment by resection of the distal part of the radius and substitution of the proximal part of the fibula

c Good bony union and good functional result The patient is fully able to work as a clerk No recurrence in three years

INTRODUCTION TO PAPERS ON AMPUTATIONS AND PROSTHESES

Tor Hierton (Uppsala, Sweden)

Once representing a surgical masterpiece amputation has gradually come to be regarded as a sign of surgical defeat. The performance often was entrusted to the less experienced member of the staff. Unfortunately it took a long time for people who had lost a limb to be fitted with a prosthesis.

The modern total contact prostheses have placed greater demands on the surgeon at the operation and during aftercare. It has become natural to regard the fitting of a modern prosthesis as a direct continuation of an orthopaedic treatment in which amputation is only the first phase in a rehabilitation programme. Amputation seen in relation to prosthesis fitting becomes a reconstructive procedure that aims to provide functional improvement and freedom from pain.

For the last 10 years these theses have been taught at the Amputee Training and Research Unit, "Gåskolan", of the University of Uppsala Orthopaedic Department.

This aroused interest among all personnel involved and the key to success was the team work: orthopaedic surgeon, physiotherapist and prosthetist centred around the patient.

IPOPF certainly has contributed a great deal to the realization of the importance of team work, atraumatic surgical technique, prevention of oedema by plastering and the great physiological effect of early prosthetic fitting.

The first main topic of our congress deals with amputation and prosthesis. On that subject a great number of interesting papers will follow.

THE CUTANEOUS BLOOD FLOW IN PATIENTS WITH GANGRENE OF THE LEGS, EXAMINED WITH 133XENON AND THERMOGRAPHY

Ole Schousbo & Danilo Zdravkovic (Odense, Denmark)

During the period of 1971–72 at the Orthopaedic Department of the Odense University Hospital, twenty-three patients with arteriosclerotic gangrene were investigated for cutaneous blood flow with 133Xenon by the method of Sejrsen (*Scand. J. clin. Lab. Invest.* Suppl. 99, 19, 52–59, 1964). The mean age was 70.2 years, with a range of 48 to 92 years. The control group (criteria for this group were foot pulses and no claudicatio symptoms) had a mean age of 58 years.

The blood flow results are shown in *Table 1*.

Table 1

Blood flow ml blood/100 g tissue/min	No. of patients	
	Gangrene	Control
0.0–0.9	6	0
1.0–2.9	8	8
3.0–4.9	5	9
5.0–6.9	3	9
7.0–8.9	1	4
9.0–10.9		2

It can be seen that there were no control cases with a cutaneous blood flow under 1 ml blood per 100 g tissue per minute We found that it was not necessary to re-amputate the crus in patients who had a blood flow of over 0 7 We could not find any correlation between healing time and cutaneous blood flow

Ten control double-sided thermographics have shown near equal thermographic status (on thighs in seven cases, on legs in nine cases), but in every case there was a difference between thigh and leg temperature On two of them thermographic findings could be considered as pathologic and in these two cases Xenon blood flow results were just above 1

Ten patients with gangrene showed only a pathologic pattern

SCANNING OF THE PERIPHERAL CIRCULATION OF THE LIMBS USING A NEW TYPE OF GLUCOSE POLYMERIC MICROSPHERE AS ISOTOPE CARRIER

Krister Wulff Ulf Rothman Bertil Nosslin & Tage Bramstång (Malmo, Sweden)

A new type of isotope labelled microsphere synthetized from glucose polymers (Rheotard, Pharmacia, Sweden) is presented It is completely broken down by the endohydrolases of the blood and the time required for break down can be changed by variation of the synthesis

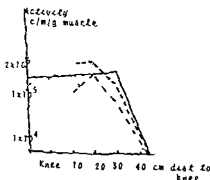


Figure 1

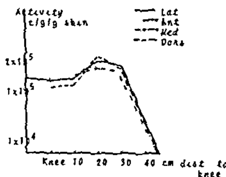


Figure 2

Figures 1 and 2 Activity of biopsies from muscle and skin respectively at different levels and aspects of the limb in a patient with arteriosclerotic circulatory insufficiency 1 mg Tc^{99} Rheotard was infused in a femoralis *preoperatively Only the muscles show different activity at the same level with reduced blood flow to the muscles of the anterior compartment*

The Tc^{99} labelled microspheres of uniform size (30 to 35 microns) have been injected into the femoral artery in patients with circulatory insufficiency The microspheres are caught in the capillary bed related to the flow and the distributions

)

circulatory

iscussed

DISTAL BLOOD PRESSURE AS GUIDANCE IN CHOICE OF AMPUTATION LEVEL

P Holstein (Copenhagen, Denmark)

In 53 BK amputations the skin blood pressure (SBP) was measured preoperatively immediately proximal to the amputation level by an isotope clearance technique Below 20 mmHg (Figure 1) reamputation on the thigh was carried out because of major wound necrosis in 75 per cent of the cases In the 20 to 40 mmHg interval reamputation was performed in 26 3 per cent in one case because of skin necrosis in four cases because of skin necrosis combined with infection or hematoma Above 40 mmHg only 7 7 per cent failed 26 cases (49 1 per cent) were classified in this relatively safe group of above 40 mmHg According to the postoperative measurements however 63 4 per cent belonged to this group Various factors may contribute to this increase in SBP a) increase of systemic blood pressure b) spontaneous improvement of the condition of the arterial pathway c) hemodynamic effect of the amputation i e elimination of a major part of the low pressure vascular bed It is possible to determine this hemodynamic effect by measuring the skin blood pressure during a pseudo amputation accomplished by a blood pressure cuff inflated to a supra systolic pressure level (Figure 2) Using a photoelectric technique SBP was determined in 43 cases 47 6 per cent had a SBP of above 40 mmHg but by employing the pseudo amputation 64 3 per cent could be registered in this group Thus a pseudo amputation is important in judging the prognosis with regard to wound healing

53 BK AMPUTATIONS

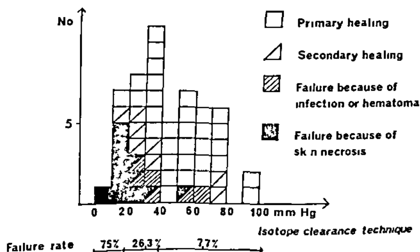
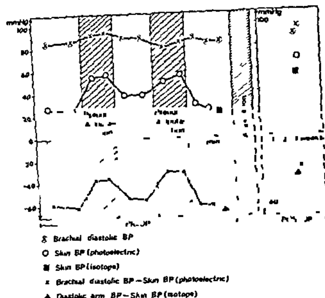


Figure 1 Results in 53 BK amputations related to preoperative measurement of the skin blood pressure (isotope clearance technique)



F gure 2 *Increase in skin blood pressure during preoperative pseudo amputation compared to postoperative measurement of skin blood pressure The wound (BK amputation) healed primarily*

BELOW KNEE AMPUTATION IN ISCHAEMIC GANGRENE SAGITTAL OR TRANSVERSAL TECHNIQUE?

N els B *Termansen* (Odense Denmark)

During the period June 1972 through 1973 a total of 72 patients had amputation carried out on the lower limb In 58 of these patients or 81 per cent 64 extremities were amputated because of ischaemic gangrene Primarily below knee amputation was done in 49 extremities (77 per cent) above knee amputation in 13 (20 per cent) and amputation on foot and toes in 2 (3 per cent)

Two techniques of below knee amputation were used a transversal technique with a long posterior flap as described by Ghormley (1946) in 26 patients (born in odd years) and a sagittal technique with medial and lateral flaps as described by Persson & Sundén (1971) in 23 patients born in even years) The incidence of d abetes was 50 per cent in the first group 35 per cent in the second one otherwise no d fferences of importance could be demonstrated between the two groups

At follow up primary healing was found in 11 patients (48 per cent) treated by sagittal technique and in 6 patients (23 per cent) treated by transversal technique. The d fference is not significant ($0.05 < P < 0.10$) The rate of revision from below knee to above-knee was the same (sagittal technique 30 per cent transversal technique 27 per cent) nor could any difference between the two techniques be demonstrated as judged by rate of local revision mortality fitting of prosthesis ambulatory or social status after amputation

PARTIAL FOOT AMPUTATIONS RESULTS AND FACTORS OF PROGNOSTIC VALUE

G B J Andersson & U Larsson (Goteborg, Sweden)

From 1959 to 1971, 196 partial foot amputations were performed on 174 subjects suffering from diabetes mellitus or arteriosclerosis Thirteen died during the early post operative course Of the remaining 183 amputations on 161 patients, 60 per cent healed distal to the ankle joint whereas 40 per cent had to be re amputated at a higher level

Ninety two were amputations of one or several toes 71 were amputations through the metatarsal bones, and 33 were amputations through or proximal to Lisfranc s joint Amputations of one toe only healed in 80 per cent of the cases Multiple toe amputations or amputations proximal to the toes healed in about 40 per cent Several operations were often necessary to achieve healing

Factors of good prognostic value were found to be related both to the lesion and to the condition of the patient Good healing was achieved when the gangrene was localized, and when the progress was slow Other favourable prognostic signs were lower age, low pre operative temperature, low ESR and normal haemoglobin value No difference was found between patients with diabetes and primary arterio sclerosis

PANEL DISCUSSION ON AMPUTATION TECHNIQUE AND POSTOPERATIVE MANAGEMENT

Moderator *T Hierton*

The panel *G Holmgren* (CPO hon Dr med by invitation), *Knud Jansen C Lindquist, B Nisses* (*Physiotherapist, by invitation*) *and Th Müller*

For prosthetic purposes the ideal stump should be well healed pain free and covered by healthy skin It is further more emphasized that length mobility and power should be adequate and the stump should have achieved a stable cylindrical or slightly conical shape The patient benefits from early exercise Information about the whole program is of importance—but often lacking

The discussion concentrated on the BK stump which nowadays is the most important site

An ultra short BK stump is to be preferred to a through knee or an AK amputation

The panel *emphasized* adequate planning and an atraumatic performance of the operative procedure In ischemia the use of the long posterior flap was recommended

The indications as well as advantages and difficulties with *Immediate Post Operative Prosthetic Fitting* (IPOPF) for ischemic and non ischemic cases were discussed

In spite of enthusiastic reports from Burgess and his research group in Seattle and their own experience the panel realized the organizational difficulties involved Accordingly *IPOPF is not* to be recommended for routine use in ischemic cases

Preventing edema of the stump by plastering and by evacuating hematoma by suction drainage were considered very important measures Early weightbearing however should be avoided—particularly in ischemic cases The short timelag between amputation and definitive prosthetic fitting was *recognized as a positive*

feature of the IPOPF program The most important effect, however, that this program has brought about has been the renewed interest in amputation technique and prosthetic fitting. In many places where team work between amputation surgeon, physiotherapist and prosthetist previously didn t exist the IPOPF program has made it mandatory Furthermore clinical research on the problems of the amputees and technical development in prosthetics have been stimulated

The moderator drew attention to two alternative methods used in Uppsala for early ambulation and early temporary prosthetic fitting in cases of *ischemia*

1 BK amputation Tubigrip + tuber ischi bearing temporary prosthesis
2 BK amputation and a *semi rigid dressing with Unna paste* around the operation site and up above the knee This light dressing prevents edema and flexion contracture of the knee One or two days post-operatively a cast is made and from this a socket is manufactured to which a pylon is attached

The Unna paste dressing which acts as a "soft liner" is readily changed for inspection of the wound Afterwards the same temporary plaster socket can be used.

This technique with semi rigid dressing so far seems to be safer and have advantages over the rigid postoperative plaster

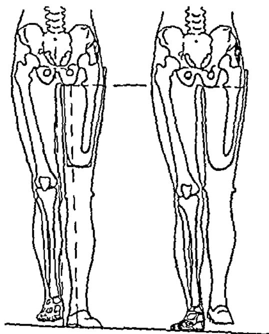


Figure 1

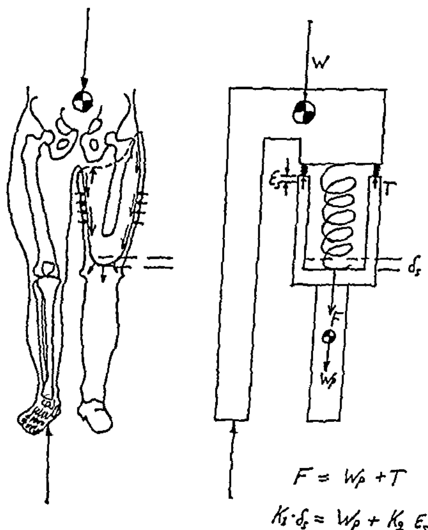


Figure 2

THE IMPORTANCE OF THE PRE STRETCHED SOFT TISSUES FOR PROSTHETIC FITTING

Kurt E T Öberg (Uppsala Sweden)

A good prosthetic fitting for leg amputees in order to transfer the *required forces* from the prosthesis to the amputation stump to give an opt mal function *depends* on many factors One very important factor is the principal of the prosthetic suspension One quantitative measure of the quality of the prosthetic suspension is the vertical relative displacement between the prosthesis and the skeleton

With the so called suction socket (below atmospheric pressure suspension) this relative displacement is reduced With an accurate shape of a closed socket an adhesion of the stump to the socket occurs because of the suction pressure In a similar manner to conventional suspension with bands *or corsets the soft tissues of*

the stump can be pre-stressed in order to get an increased suspension also for the suction socket *With an increased pre-stretching* of the soft tissues their stiffness increases allowing a better suspension of the prosthesis

... amputee more freedom *and comfort* and better func-

tic ... ist,

also the strong personal involvement of the patient. He must ... on his prosthesis in the right way by himself

DYNAMIC DEMANDS ON SOCKET CONSTRUCTION

Gunnar Holmgren (Uppsala, Sweden)

The compensatory effect of a prosthesis depends upon the stability of attachment *between prosthesis and body* As the femur is surrounded by displaceable soft tissues this attachment is rendered difficult, and unless a satisfactory connection is achieved both the effect and transmission of power will be reduced, *with consequent* difficulty in walking

To increase stability negative pressure and total contact are used and the soft tissues are intentionally deformed to produce some tension

In constructing the socket it must be remembered that different pressures are exerted over different stump regions Active muscles must also be considered Thus the socket cannot exactly reflect the stump configuration, e g proximally in the *horizontal plane it is rectangular*

The four muscle groups to be especially considered are the long knee flexors, rectus femoris adductor longus and gluteus maximus These muscles must be given room to function satisfactorily

The medial and posterial radius of the socket brim must be well adapted to the stump If it is too small it will prevent hip extension, if it is too big a large support area for taking up weight vertically is lost

The socket wall height is determined by the pressure and counterpressure to be established with regard to the ischial tuberosity

STUDIES OF THE SUSPENSION OF BELOW KNEE (BK) PROSTHESES

Sven Grevsten (Uppsala Sweden)

Since 1969 the suction PTB prosthesis for below knee amputations has been clinically *tried at the Orthopaedic Department in Uppsala*

This prosthesis is an analogue suspension to the suction prosthesis for above-knee amputations The difference in mechanics and soft tissue relations above and below the knee means quite different *considerations when constructing the* socket

Studies were performed to describe the relations in the BK socket

A roentgenological study analysed the stump movements in imitated walking The vertical displacement of the amputation stump was *on average 1 25 cm less* in the suction prosthesis than in the PTB prosthesis

A study of the pressure variation showed level differences in the pressure, negative pressure in swing phase and positive pressure in stance phase

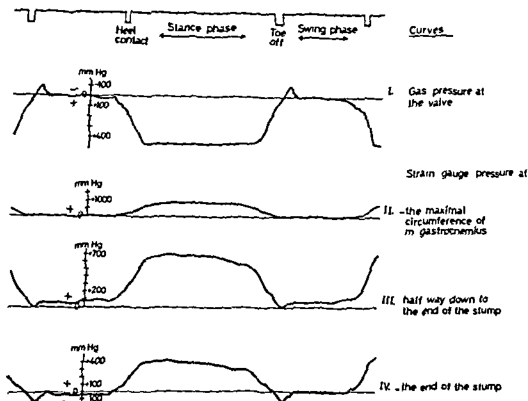


Figure 1 Pressure variations for the stump end socket cavity and for posterior limb socket interface surfaces at progressively lower levels Note that trace I is inverted and that scales for traces I and II are different

An electromyographic study of the amputation stump while walking with a suction prosthesis has shown that the muscular activity pattern is similar to that *in a normal leg* Walking with the PTB prosthesis there are usually simultaneous contractions of antagonistic muscles

An optimal prosthetic suspension must simultaneously counteract movements in the socket and distribute the load over the stump Thus a socket should have

1 the shape of the individual stump and
2 and adhesive fixation in the socket but
3 the adhesive fixation means only a minimal compression of the soft tissues Otherwise the circulation in the stump is jeopardized

The total contact in a suction prosthesis has

1 a lower pressure at the bottom of the socket than higher up
2 friction in the socket
3 the adhesive effect between two surfaces

STUDIES OF MUSCLE STRENGTH AND PROSTHETIC ATTACHMENT IN ABOVE KNEE AMPUTEES

Urban James (Uddevalla Sweden)

A group of healthy active male unilateral above knee amputees were studied The mean stump length was two thirds of the length of the intact femur All were fitted with a total contact suction socket

Mean total cross sectional area of the amputation stump was calculated to be 63 per cent of that of the intact thigh. Mean cross sectional area of skin and subcutaneous tissue of the stump exceeded that of the intact thigh by 12 per cent ($0.01 > P > 0.001$) Muscle and bone tissues of the stump were 55 per cent ($P < 0.001$) and 27 per cent ($0.01 > P > 0.001$) less respectively than those of the intact thigh In the stump skin and subcutaneous tissue were calculated to occupy a mean of 41.8 per cent muscle 53 9 per cent and bone 4 3 per cent of the total cross sectional area Corresponding tissue proportions in the intact thigh were 21 3 per cent 75 0 per cent and 3 7 per cent

In relation to the intact side the hip joint on the amputation side exhibited a reduction in strength of the flexor extensor abductor and adductor muscles of approximately the same extent i e 43–48 per cent on an average The muscle strength in the hip joint on the amputation side like the relative volume of the stump was significantly correlated to the stump length

The femoral stump showed appreciable movement in the soft tissues within the socket An arc of considerable dimension at the level of the knee and the sole of the foot corresponded to observed changes in angulation of the femoral stump within the socket On full weightbearing on the prosthesis alone the distal end of the femur assumed its most distal lateral and posterior position obviously as a result of active muscular function for achievement of lateral stabilization of the pelvis and prevention of flexion (collapse) of the prosthetic knee joint

A NEW LEG PROSTHESIS SOCKET

Per Renstrom Ian Goldie & Tryggve Eeg Olofsson (Goteborg Sweden)

A crucial problem for the leg amputee is the connection between the amputation stump and the socket of the prosthesis Looseness of the socket results in instability excessive tightness impairs the circulation and causes tissue damage We have designed a socket with the object of providing a closer adjustment to the constantly varying shape of the stump thus giving the individual the sensation of being "at one with his artificial leg

The socket bottom consists of a floating pad filled with ordinary water connected to a pivot in the leg shell Thus the socket adjusts itself to circumferential and longitudinal variations of the amputation stump The amputation stump rests on a floating pad (1) which is attached to a cup (2) affixed to the pivot (3) The pivot can be lowered or heightened by turning the screw (4) which protrudes slightly outside the shell for manual control by the bearer Because of the characteristic incompressibility of a fluid the connection between the amputation stump and the prosthesis becomes very solid This solid connection gives very good contact with the ground for the bearer

Figure 1

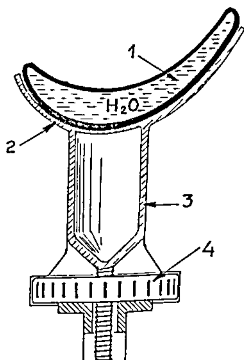


Figure 2

This prosthesis has been used for three very difficult amputation stumps during a five month trial period One patient is a young man who for three years had continuous trouble and had tried no less than eight prostheses *During the time* he has used the new design his skin wounds have healed and he has been able to run to do a full day s work to drive a car and to dance *He has also reached full* social adaptation

METHODS FOR EVALUATION OF PROSTHETIC GAIT

Kurt E T Öberg & Urban James (Uppsala Sweden)

Studies of prosthetic *gait can be made from different* aspects. In general a physical description of gait can be contained by the following factors

Characteristic events	temporal factors
Motion	– displacement
Dynamics	changes of forces

A variety of measuring methods are available There are optical methods and electromechanical methods Also electromyography gives important information towards the physical description of gait as well as the physiological description

In the clinic the following gait characteristic variables are measured

Swing and stance duration
Step length and stride width
Knee angles

The measuring equipment consists of

Test *shoes with heel and foot switches*
Paper on the walkway for footprints
Electrogoniometers
Multichannel recorder

An additional non instrumented study is also made for estimating the behavior of different prostheses when the amputee is walking on different walkways such *as stairs* ramps etc

From the measured data other important variables such as gait velocity and step *frequency can be calculated*

For each patient comparison with normal gait can be done with respect to each variable *For unilateral amputees the asymmetry of the gait represented by the* difference between the intact leg and the prosthetic leg for each variable can be studied.

For a more detailed study of the prosthetic gait a measuring and analysing method is being developed Using a measuring instrument (SELSPOT) the gait motion and the floor reaction forces are measured The instrument is connected online to a computer where the data can be processed immediately

PHYSICAL WORK PERFORMED BY SURGEONS DURING ORTHOPAEDIC OPERATIONS

Paul Lereim (Oslo Norway)

Four surgeons participated in a study which aimed to demonstrate the physical work load during *operations Maximal* oxygen uptake and maximum heart rate

were determined by using the Douglas bag technique and recording the heart rate during the tests By working at two submaximal work loads heart rate was recorded and maximal oxygen uptake was determined indirectly

Using telemetry heart rate was recorded during the operation and so the mean oxygen uptake could be determined In 90 per cent of all operations the surgeons were working at a level of 20 to 30 per cent of their maximal aerobic capacity

There was an increase in body temperature and a decrease in body weight with all operations With very long operations a decrease of grip force was noted My conclusion is that regular physical exercise would make the surgeon better prepared for his daily work and hence be of benefit to his patients

INABILITY TO WORK AFTER INJURIES THE RELIABILITY OF PRIMARY PROGNOSTICATION

F L Nordentoft W Damholt P K Pedersen & A Tilma (Odense Denmark)

The purpose of the investigation was to set up a simple model of graduation of severity of injuries regardless of their nature or localization The primary attending physician made an estimate as to the resulting disability in a large group of patients The estimation was reexamined by checking on the duration of inability to work in 328 who normally do physical work in the age range 25–50 years all injured in traffic accidents There was a wide scatter of results within the individual prognosis groups However with a fair amount of certainty it was possible to define the time when 50 per cent of the injured persons had resumed work and then to relate this to the estimated prognosis

The method is judged to be applicable in cost accounting in cost benefit analysis and possibly as a basis of prepayment of daily benefits

POSTOPERATIVE RESTORATION OF MUSCLE STRENGTH AFTER INTRAMEDULLARY NAILING OF FRACTURES OF THE FEMORAL SHAFT

Goran Danckwardt Lilliestrom & Staffan Sjogren (Uppsala Sweden)

During the period 1964 1969 a total of 45 patients with fractures of the femoral shaft were treated by intramedullary nailing after reaming In 23 of them the isometric muscle strength on hip abduction knee flexion and knee extension was measured The values obtained were compared with values collected earlier from a reference material The results indicated that as a rule the muscle strength in the intact leg was restored to almost a normal degree in two years The restoration in the treated leg particularly for knee flexion and knee extension was significantly poorer Even in the best group of patients those below 50 years of age with a femoral fracture alone and with an observation time of more than 2 years the muscle strength on knee extension and knee flexion was lower than in the intact leg (9 0 Kp significant and 3 4 Kp almost significant respectively)

A rotation deformity in the fracture area seems to reduce the ability to regain muscle power in the treated as well as in the intact leg

Reference

Danckwardt Lilliestrom G (1973) Intramedullary nailing of femoral shaft fractures after reaming of the medullary cavity *Acta chir scand* **139** 155 166

POSTTRAUMATIC CHANGES OF SERUM IRON (FERRO KINETIC STUDIES)

Danilo Zdravkovic (Odense Denmark)

A constant and very strong decrease in serum iron after operative trauma was demonstrated in a selected group of patients To investigate the problem, ferro kinetics were used on dogs Five dogs were subjected to transverse femur osteot om es as artificial fractures which were fixed with plates Six dogs without trauma or anaesthesia and five dogs under anaesthesia alone were used as controls The disappearance time for iron isotope (^{59}Fe) fr m plasma was less in the oper ated dogs and ... of isotope was observed in hepar lien and bone marr ... bone marrow ... method with ... the reticulo endothelial system in posttraumatic iron metabolism ... tions showed that the affinity of the reticulo endothelial system for iron is in creased posttraumatically and releasing of iron from the reticulo-endothelial sys tem is blocked for a short period of time (about 14 days) Thus bone marrow has a shortage of iron for red blood cell production but purpose of this phenomenon is not yet known

DICLOXACILLIN (DICLOCIL®) IN NON SPECIFIC OSTITIS AND OSTEOMYELITIS

Per Holstein & Ole Hvid Hansen (Hillerød Denmark)

During the period 1 11 1967–31 10 1968 a consecutive and prospective series of 25 patients with non specific ostitis or osteomyelitis was treated with dicloxacilline Diclocil®) as an adjuvant to surgical therapy In cases of infected osteosynthesis the practice was to let the osteosynthesis material remain in situ until stability at the fracture had been achieved In 20 patients the infection healed during treat ment and in one patient the infection healed spontaneously later Below knee amputation had to be undertaken in one patient and in three patients fistulae persisted The follow up period was 1–3 years Dicloxacilline was found suitable for long term therapy in bone infections Side effects were few and no toxic dam age to bone marrow liver or kidney was registered

LATE DIAGNOSED HIP JOINT DISLOCATION IN CHILDREN

Kurt Palmen (Falkoping Sweden)

During 1973 a total of 54 cases of late i e after the newborn period diagnosed hip joint dislocation or dysplasia in children were treated in the Swedish ortho paedic clinics Only 13 came after one year of age 39 were diagnosed between one to 6 months Out of these six had luxation six had subluxation and eight a slight dysplasia

In 19 cases the diagnosis was uncertain In my opinion several of these have had limited abduction owing to pelvic obliquity caused by a habitual one-sided posture In such cases the X ray examination is often misleading as the pelvic obliquity among other things gives a false increase to the acetabular angle Such one sided limited abduction disappears spontaneously during infancy

49 cases were born at maternity clinics where a paediatric consultant trained in hip joint examination examined all the newborn. So we must accept that the diagnosis of hip dislocation cannot be made in the newborn period in a few cases.

In all cases during the second year of life it has been the mothers who have detected the limp in the children and come for help. To obtain an early diagnosis it is important to inform the doctors at the child health centres to examine the hip joints at every health check.

CONSERVATIVE TREATMENT AND OSTEOTOMY IN COXA PLANA. A RADIOLOGICAL STUDY

Tage Marklund & Bengt Tillberg (Linköping, Sweden)

The course of the disease and the primary end results have been compared in two treatment groups of coxa plana patients. One group was conservatively treated (33 patients—Thomas' splint) and the other group was submitted to osteotomy (28 patients—subtrochanteric *derotation and varus osteotomy*). The osteotomy group was younger on the average. The epiphyseal changes at discovery were also more advanced, indicating that the osteotomy treatment was given later in the disease than the conservative treatment.

For each patient a curve was made representing the course of the disease. From the serial radiographs the extent of the involvement of the epiphysis was assessed and plotted as a percentage of the normal epiphyseal volume against time. The curve has a descending part—the destructive phase and an ascending part—the phase of reconstruction. The turning point is situated where destruction changes into reconstruction.

In each group the curves were superimposed with their turning points coincident in time. The two sets of curves were then compared. There are no obvious differences between the two groups in the rates of destruction and reconstruction. This was statistically confirmed. The distribution of the extent of the maximal involvement is the same in the two groups.

In the same groups the primary end results were assessed. The deformity of the femoral heads was *visually judged and classified from the radiographs. The slightly* better result in the osteotomy group can be explained by the age distribution.

The course of the disease is obviously the same in the two groups. Osteotomy has *neither arrested the destructive phase* nor influenced the rate of reconstruction. The end results (the shapes of the femoral heads) were roughly the same in the two groups. The conclusion is that the effect of the two treatments would seem to be *equally* good, equally bad or equally futile.

CORRECTION OSTEOTOMY OF THE TALUS AND CALCANEUS IN RELAPSING OR INCORRIGIBLE CLUBFEET. PRINCIPLES AND TECHNIQUE

Åke Hjelmstedt (Uppsala, Sweden)

In congenital clubfeet where conservative treatment has failed operative correction is indicated. In infants the choice of procedure has mainly been based on clinical examination. Detailed information of the skeletal deformity can, however, now be obtained by arthrography of the ankle and talonavicular joints.



Figure 1 a Lateral view of a clubfoot talus Note the flattening of the trochlea and plantar deviation of the neck and head The osteotomy lines are marked with short dashes The cross indicates that the base of the wedge should as a rule be on the dorsolateral side of the neck

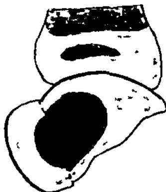


Figure 1 b Correction after wedge osteotomy The actual shortening of the talus will be about 10 per cent of its former length

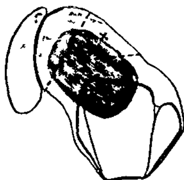


Figure 2 a A clubfoot talus and the navicular bone from above The joint borders are marked with broad lines and the osteotomy lines with short dashes Note the pronounced medial deviation of the talar neck and head and the obliteration of the original talonavicular joint

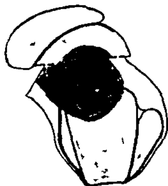


Figure 2 b Correction after osteotomy

The arthrogram will often show a pronounced plantar deviation of the talar head even when the talus is in maximal dorsiflexion (Figure 1 a) Correction seems possible only by performing wedge osteotomy (Figure 1 b)

Pronounced medial deviation of the talar head is a common feature and when

it is combined with an obliteration of the original talonavicular joint (Figure 2 a) correction by osteotomy seems to be the only rational procedure (Figure 2 b)

A wedge osteotomy through the distal part of the calcaneus is done simultaneously

The operation also includes the following procedures

1 always a lengthening of the posterior tibial tendon and section of the tibio navicular ligament
2 as a rule an extra periosteal release of the plantar fascia and the abductor hallucis muscle and shortening of the peroneal tendons
3 sometimes a lengthening of the tendon Achillae the necessity for which is based on the arthrographic study of the ankle joint mobility

CRURAL FRACTURES IN CHILDREN

J Greiff B A Hansen C F Bergman (Gentofte Denmark)

Eighty one patients with fissures infractions and fractures in the lower leg were studied 13–36 months after the trauma A spot orthoradiogram was made and analysed It was found that the increase in growth depended on the age generally on the angulation at the time healing had occurred and around puberty also on sex

Furthermore it showed that the difference in the tibial length caused by a fracture is not of significance for the well being of the patients

The conclusion made was that crural fractures in children especially around and after puberty should be treated with the same claim for reduction as in adults spontaneous correction being somewhat less frequent than generally agreed

THE EFFECT OF PSEUDARTHROSIS ON LONGITUDINAL GROWTH

Soini Ryoppy Reijo Malinen & Erkki Karaharju (Helsinki Finland)

The experience acquired from clinical practice shows that a congenital or acquired pseudarthrosis causes a diminution of longitudinal growth Theoretically this phenomenon could have several pathogenic factors e g change of mechanical stresses to the bone change of circulation etc Very little information is available about the factors involved

In this study the effect of an experimentally produced non union on the longitudinal growth of the fibula and the tibia was investigated using the rabbit An operative resection of the fibula was performed on rabbits aged three weeks The union was prohibited by placing a polyethylene film between the fragments Metallic markers were placed in the tibia and the fibula and the longitudinal growth was checked weekly by X ray The animals still in the growing period were given oxytetracycline one week before sacrifice at six to twenty eight weeks after the operation

The growth of the tibia of the operated leg was slightly retarded compared to the control side The longitudinal growth of the operated fibula was statistically significantly retarded some weeks after the operation (Figure 1) On the animals with fusion of the resected area the growth of the fibula continued almost normally The growth of the fibula with non union took place at a slower rate than that of the control side but otherwise the growth curves had the same form

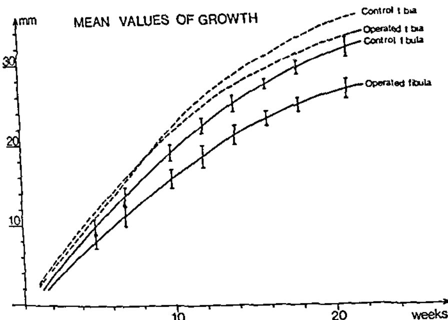


Figure 1 Mean values of longitudinal growth of the proximal epiphysis of the leg with an experimentally produced non union of the fibula on the rabbit

From the evidence obtained it is concluded that

1 An experimentally produced non union in a growing long bone causes a gradually increasing retardation of the longitudinal growth
2 This phenomenon can be produced without functional inactivity
3 It seems evident that the cause of this phenomenon is not a circulatory one Instead the epiphyseal growth is probably dependent on the mechanical stimulus transmitted by the continuity of the bone

OPERATIVE TREATMENT FOR GROWTH DISTURBANCE AFTER EPIPHYSEAL INJURY

A *Langenskiold* Helsinki Finland)

In 1967 the author reported a case in which a deformity in the tibia had been caused by a bony bridge between the epiphysis and the metaphysis The deformity was partly corrected by growth after resection of the bone bridge and its replacement with a free fat transplant

After experimental studies on animals nine children with partial premature epiphyseal closure were operated on with a positive result The effect of the operation is based on three experimentally proved facts 1 When part of an epiphyseal plate is destroyed and the formation of bone tissue uniting the epiphysis to the metaphysis is prevented the destroyed portion of cartilage is replaced by regeneration of cartilage from the adjacent parts of the plate (Langenskiold & Edgren

Acta chir scand (1949) 99 353) 2 When a bone bridge connecting an epiphysis to a metaphysis is resected and replaced with a free fat transplant recurrence of the bone bridge is prevented 3 When the deforming effect of partial premature closure of a growth plate is eliminated gradual correction of the deformity by growth can take place (Österman *Acta orthop scand* (1972) Suppl 147)

Two of the operated cases in which an angulation deformity of 20–30 degrees was completely corrected by growth are reported

STUDIES OF GROWTH HORMONE IN GIRLS WITH IDIOPATHIC STRUCTURAL SCOLIOSIS

S Willner K O Nilsson C C G Bergstrand (Lund Sweden)

It has been noticed that girls with idiopathic scoliosis are taller (even before the diagnosis has been made) and leaner than comparable nonscoliotic controls in Sweden (Willner *Clin Orthop* (1974) in press)

It was thought that this difference might be related to the growth hormone (GH) and for this reason GH was determined in plasma by double antibody radio immunoassay during the following conditions 1 insulin hypoglycemia 2 glucose tolerance test 3 exercise

Results

A After overnight fasting and after at least one hour of rest the GH level was 9 8 ± 11 1 ng/ml in the scoliotic girls ($n = 48$) and 2 2 ± 1 1 ng/ml in the controls ($n = 15$) The difference is significant ($0\ 02 > P > 0\ 01$) B In the insulin hypo glycemia test the peak GH value was 33 2 ± 19 1 ng/ml in the scoliotic girls ($n = 27$) and 20 8 ± 8 3 ng/ml in the controls ($n = 8$) This difference is how ever not significant ($0\ 1 > P > 0\ 05$) C In the exercise test the maximal value was observed at different times from the start of the test at 20 minutes in the scoliotic girls ($n = 14$ GH 17 3 ± 11 8 ng/ml) and at 40 minutes in the controls ($n = 9$ GH 16 0 + 6 6 ng/ml) D In the glucose tolerance test the GH level was suppressed in both groups but the mean GH levels tended to be higher during the first 120 minutes of the test in the scoliotic girls

Conclusion

The observed differences in growth hormone response during the various tests including statistically significant higher basal values could indicate an increased GH secretion in idiopathic scoliosis

NUCLEIC ACIDS IN HUMAN ARTICULAR CARTILAGE—NORMAL AND OSTEOARTHRITIC

Hans Telhag (Malmo Sweden)

Adult joint cartilage was formerly regarded as a tissue with relatively little metabolic activity Research during the past few decades has shown however that degenerative changes of the cartilage are accompanied by an increased synthesis of DNA glycosaminoglycans and collagen changes which are regarded as signs of repair

At operations on joints of patients with osteoarthritis specimens of severely degenerated cartilage of the femoral head were removed and as control material, cartilage from knee joints at meniscectomy. DNA and RNA concentrations were reduced in advanced osteoarthritis whereas synthesis of DNA and RNA was increased in relation to the number of cells in the tissue. Since there is a constant relationship between the DNA concentration and the number of cells in the tissue the investigation shows that the remaining chondrocytes in the markedly degenerated cartilage are metabolically more active than those in normal cartilage.

LATE OSTEOARTHRITIS OF THE HIP AND KNEE JOINT IN NORWEGIAN FOOTBALL PLAYERS

Asbjørn Roaas & Ragnar Bjørn Hansen (Sandvika, Norway)

Twenty five former football players were compared with 25 persons who had not taken part in any athletic activity.

There was no significant difference in occurrence of osteoarthritis of the hip joints between the two groups as judged by roentgenological and clinical examinations.

As regards the knee joints, there were 40 with osteoarthritis in the football group against 35 in the control group, but there was a greater occurrence of varus in the football group and more osteoarthritis in the varus than in the valgus group. Furthermore there were more overweight footballers.

It is concluded that there is no significant difference in the frequency of osteoarthritis of the hip or knee joints in the two groups. It seems that "overuse" or "repeated micro traumas" do not play any important role in the development of osteoarthritis in the hip and knee joints.

GUNSTON ARTHROPLASTY OF THE KNEE

Uolevi Kankaanpää & Pauli Raunio (Heinola, Finland)

From 1971 to 1973 Gunston arthroplasty was performed at the Rheumatism Foundation Hospital, Heinola on 54 knees in 50 patients afflicted with rheumatoid arthritis. Fifty of the knees have been followed up from 6 months to 3 years (average 1 year and 6 months). The mean age of the patients was 51 years (ranging from 27 to 62 years).

At first the indications for arthroplasty were the same as for arthrodesis, but later they were modified.

The alleviation of pain was the greatest benefit from the procedure in the pa

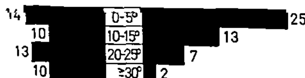


Figure 1. Distribution of the knees according to the degree of flexion contracture pre- and postoperatively.

Table 1 Distribution of the knees into the categories of pain in the first and second operation period.

Oper period	Pain category				Total
	0	1	2	3	
I	6	9	7	1	23
II	4	20	1	0	25
total	10	29	8	1	48

tients' opinion as well Forty-five out of 50 patients felt that the knee had markedly improved after surgery. Knees without pain totalled 10 (20 per cent), and in 29 knees (58 per cent) there was intermittent pain while walking

When the material was divided into two chronological groups, one with a follow-up of 2 years and 6 months (operation period I) and the other with a follow up of 1 year and 3 months (operation period II), the former group showed poorer results (Table 1) The categories of pain were· 0 = no pain, 1 = intermittent pain, 2 = continuous pain on attempting to walk, 3 = severe pain

The mean decrease in flexion was 11° (103°–92°), whereas the decrease in range of movement averaged 3° (85°–82°)

The improvement of flexion contracture was good (Figure 1)

Prior to surgery the number of unstable knees totalled 34 (more than 5° instability when loaded) and the stable ones numbered 14 After surgery the situation was almost the reverse, the unstable totalled 13 and the stable 35 Out of the postoperative complications three knees with deep infection may be mentioned Geometric arthroplasty was performed on one of these at a later stage and the other two were fused in connection with the removal of the endoprosthesis Furthermore, two femoral prostheses were broken, one breakage led to arthrodesis and the other was one of the cases of deep infection mentioned above

Narrowing of the joint space, which was considered to be due to the tibial prosthesis sinking into the bone as well as to the HDP plastic wearing off, was revealed roentgenologically in 22 out of 48 patients during the follow up The intensity of these changes was in direct relation to the length of the follow-up

RECONSTRUCTION OF THE KNEE JOINT WITH THE FREEMAN-SWANSON PROSTHESIS

Peter Herberts & Gunnar Andersson (Goteborg Sweden)

Preliminary results were presented of twenty knee arthroplasties using the Freeman Swanson knee prosthesis Nineteen patients had severe rheumatoid arthritis, one patient had an advanced osteoarthrosis All patients were studied preoperatively and postoperatively at fixed intervals in relation to the operation The operation was offered to those who were chair-bound and to those patients who would accept an arthrodesis Time of observation varied from six to twenty-four months Pain, walking ability, range of movement, flexion deformity and valgus or varus deformity combined with instability were evaluated In an attempt to make a total assessment of the procedure 75 per cent were graded as good They

were pain free able to walk outdoors and had a range of movement from −5° to 90° The knees were stable and showed a varus or valgus deformity of less than 10° Twenty per cent were improved and graded as acceptable and only 5 per cent were unchanged or deteriorated and graded as poor No infection or loosening was observed in this study

ALLERGIC COBALT REACTION (METALLOSIS) FOLLOWING KNEE ARTHROPLASTY WITH VITALLIUM ENDOPROSTHESIS *AD MODUM* WALLDIUS

Anders Wigren & Torkel Fischer (Uppsala Sweden)

A case report is given of a woman with rheumatoid arthritis and severely deformed knee joints She had a knee arthroplasty with a metal to metal Vitallium endoprosthesis *ad modum* Walldius Eight months after the arthroplasty a sterile fistulation began from the knee joint The fistula was closed operatively Fifteen months after the arthroplasty there was eczema of the skin of the operated knee The eczema followed the projection of the contours of the endoprosthesis on the skin An epicutaneous test for cobalt before the arthroplasty was negative Fifteen months after the operation it was positive A pathological investigation of the eczema and the epicutaneous test area of the skin showed deep inflammatory reaction equal for the eczema and test skin area

The patient had no pain in the operated knee and the function of the prosthesis was good throughout the observation time

Treatment with local steroids made the eczema disappear in 3 months It is suggested that the metal to metal contact will increase the release of ions from the cobalt chromium alloy Vitallium and that the proximity of the prosthesis to the skin is a possible explanation for the skin reaction

CIRCULATORY AND RESPIRATORY DYSFUNCTION DURING TOTAL HIP REPLACEMENT

The importance of thromboplastic products fat embolism and acrylic monomers

Jan Modig Christer Busch & Sven Olerud (Uppsala Sweden)

The operative procedure of total hip replacement involves a considerable trauma and there are many reports in the literature of serious cardiovascular reactions and even deaths during intramedullary orthopaedic surgery using acrylic bone cement These complications occur notably following impaction of the femoral prosthesis into the bone marrow cavity filled with acrylic cement Many tentative explanations for these reactions have been suggested

In order to study this more closely an investigation concerning respiration circulation and coagulation was performed in patients undergoing prosthetic hip surgery using the Charnley technique Operations were performed under epidural analgesia with the patients awake and breathing air Additional experimental work with intravenous injections of acrylic monomers was performed in dogs

Major respiratory and circulatory depressions occurred regularly after impaction of the femoral prosthesis and minor depressions appeared after insertion of the acetabular prosthesis. It is established from these studies that the circulatory and respiratory phenomena are mainly caused by the release of tissue thromboplastic

products into the circulation causing aggregation of platelets and fibrin in the lungs i e intravascular coagulation The fat droplets *per se* in the pulmonary circulation are of minor importance and the release of acrylic monomers into the lungs is probably of no importance

INTRAOSSEOUS PRESSURE OF THE FEMORAL HEAD BEFORE AND ONE TO THREE YEARS AFTER OSTEOTOMY IN OSTEOARTHRITIS OF THE HIP JOINT

N B Termansen & K Okholm (Odense Denmark)

In 22 patients with osteoarthritis of the hip joint intraosseous pressure was measured before and 11½ to 33½ months after intertrochanteric osteotomy The mean pressure of the femoral head was higher than that of the greater trochanter After healing of the osteotomy the mean pressure of the femoral head in all 22 patients was reduced but not significantly Significant reduction of pressure was found in patients with high primary pressures (above 35 mmHg) and in patients re examined less than 2 years after osteotomy whereas there was a tendency for increasing pressure after that time—The clinical effect of the operation was good Only one patient suffered from rest pains at the re examination—Disappearance of rest pains may be explained by reduction of intraosseous hypertension lasting for some years After that intraosseous hypertension might be slowly re established

FEMORAL FRACTURES AFTER MOORE ARTHROPLASTY OR McLAUGHLIN OSTEOSYNTHESIS

Borge Ruben Hansen (Copenhagen Denmark)

The insertion of an inert surgical implant in living bone alters the biomechanical factors and induces stress concentrations in the transmission zones Loading of the system repeatedly results in minute relative movements between the implant and the bone and may be the fundamental cause of a late fracture

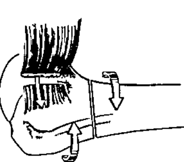
Thirty six patients with a hip prosthesis and twenty three patients with a proximal internal fixation sustained a secondary fracture Most of the fractures were localized to or below the level of the shaft of the prosthesis or the McLaughlin plate—all were oblique fractures with considerable instability

In unstable fractures secondary to a Moore arthroplasty an internal fixation with a lateral eight hole plate has been considered the most convenient method In fractures secondary to a McLaughlin operation the original implant has been re placed with a long plate McLaughlin

RECURRENT DISLOCATION OF THE SHOULDER TREATMENT WITH SUB CAPITAL ROTATION OSTEOTOMY

B G Weber (St Gallen Switzerland)

Most procedures such as tightening up the enlarged anterior soft tissue compart ment of dislocating shoulders are successful as they more or less limit external rotation This general experience applies to our own 60 patients operated on from 1960 to 1966 with a modified Putti Platt technique On the average these patients showed a loss of external rotation of 32°—none of them had a recurrence



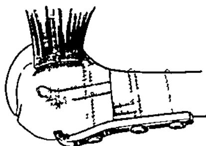
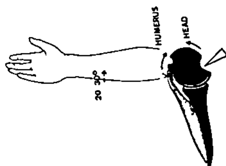


Figure 1 c



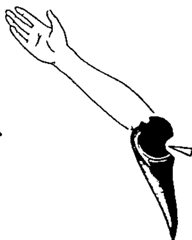
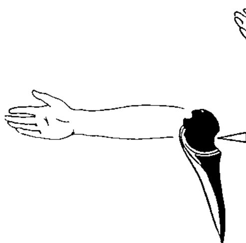


Figure 1 b



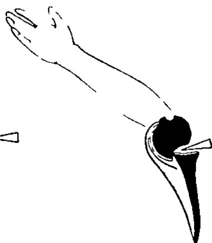


Figure 1 a

Once in 1964 and another 67 times, from 1967 to 1972, in cases with a marked 'encoche de Malgaigne', i e a typical impression fracture of the humeral head on its posterior surface (*Hill Sachs, Hermodson*) an operation was tried out according to the idea demonstrated in Figure 1

a) Subluxation occurs in external rotation as the posterior humeral defect slips over the anterior glenoid margin
b) Prior external rotation allows the posterior defect no access to the glenoid rim for dislocation to occur, if by means of an osteotomy the humeral head has been rotated inwards in relation to the long axis of the humeral shaft
c) Such a rotation osteotomy of 20 to 25 degrees, performed from a standard delto pectoral aproach, is stabilised with an adapted small AO-compression plate, actually refined as a dynamic compression plate The subscapularis tendon is shortened at the same time by 1 cm

The aftercare is very simple No splintage is needed, but free movements may be allowed a few days after operation, progressing to full mobility in 6–8 weeks, in step with healing of the osteotomy

In our whole series of 68 cases, no recurrence has occurred One case had a low grade infection with staphylococcus albus, subsiding after removal of the plate but never the less had a perfect end result In contrast to many other operations, the osteotomy described does not sacrifice joint mobility there is free external rotation, a fact not only very important to sportsmen but also in every day life

FRACTURE OF THE SHAFT OF THE TIBIA

Per Edwards (Malmo Sweden)

The prognosis of a tibial fracture is above all dependent on
1) The etiology—the type of fracture
2) The extent of soft tissue injury—the size and location of the wound
3) Complications—especially infection
4) The age of the patient

The difficulty in comparing different methods of treatment lies in the fact that there are no universally accepted definitions of the different variables The type of fracture, the extent of soft tissue injury the evaluation of healing time and the end result etc

It is proposed that the Scandinavian Orthopaedic Society defines these variables for publishing of papers in Acta orthop scand

Open treatment of closed tibial fractures of the transverse type causes a high frequency of complications especially when treated by AO compression osteo synthesis (Olerud & Karlstrom 1972) The use of the AO plate on a large scale does not seem to improve the functional end results (Bender 1970)

A careful estimate of the value of new closed methods is of great importance therefore a prospective series has been started in Lund and Malmo treating different types of tibial fracture with PTB cast with a movable ankle joint according to Sarmiento

Open fractures, especially those with big lacerations of the skin, are the great problem I think that the treatment of those fractures should be centralized

PRIMARY OPERATIVE TREATMENT OF LONG BONE FRACTURES IN PATIENTS WITH MULTIPLE INJURIES

Erik B Riska & Timo Paavilainen (Helsinki Finland)

Early mobilization is essential for patients with multiple injuries in order to prevent thrombo embolic disease weakening of muscle power, stiffening of joints psychical inactivity and hospitalization perhaps even death This applies partic ularly to the treatment of patients with several long bone fractures together with

Table 1 Long bone fractures in 33 patients with multiple injuries

Bone	Number	Number of open fractures
Femur	42	9
Tibia	22	10
Fibula	19	10
Humerus	6	
Radius	11	
Ulna	10	2
Total	110	31

Table 2 Methods of osteosynthesis of long bone fractures in 33 patients with multiple injuries

Method of osteosynthesis	Number of bones treated operatively
Intramedullary nailing (Kuentscher)	40
of femur	27
of tibia	12
of humerus	1
Screw and L-plate fixation (AO)	8
of distal femur	8
Screw and plate fixation (AO)	17
of femur	1
of humerus	2
of radius	6
of ulna	8
Screw fixation (AO)	4
of tibial condyle	4
Osteotaxis (Hoffmann)	3
of tibia	3
Jewett Barnes or McLaughlin	6
of femoral neck	6
Total number of long bones	78

Table 3 Treatment of associated injuries in 33 patients with multiple injuries and operatively treated long-bone fractures.

Methods of treatment	Number of cases
Thoracotomy	2
Abdominal operation	3
Tracheostomy	5
Antero-lateral decompression	1
Osteosynthesis of pelvis (AO)	2
Screw fixation of short bones (AO)	4
Repair of injured ligaments	3
Patellectomy	2
Resection of aortic arch	1
Repair of big artery	1
Osteosynthesis of facial bones	2

Table 4 Mobilization, and duration of hospital treatment of 33 patients with multiple injuries and operatively treated long bone fractures

Mobilization on crutches after	Number of patients	Duration of hospital treatment	Number of patients
3 weeks	2	3 weeks	2
4 „	5	4 „	6
5 „	1	5 „	2
6–7 „	7	6–7 „	3
2 months	2	2 months	3
2½ „	5	2½ „	5
3 „	5	3 „	3
3½ „	3	3½ „	3
11 „	1	4 „	2
Bedridden	1	5% „	3
Death	1	Bedridden	1
Total	33	Total	33

other injuries The conservative treatment of these fractures with reduction and plaster immobilization was one of the main factors in preventing early mobilization and has therefore been replaced in our clinic by rigid internal fixation since 1969 Ever since that year and up to 1972 thirty three patients with multiple injuries and at least two long bone fractures were treated at the intensive care unit after which the hospital treatment was continued traditionally

Of these 33 consecutive cases, 24 were men and 9 women 25 were under 50 years and 8 aged over 55 years at the time of the accident All together 110 long bones were broken in 33 patients (Table 1) Thirty one were open fractures Additionally,

Table 5 Results of treatment of 33 patients with multiple injuries and operatively treated long bone fractures

Working capacity	Number of patients
Returned to former work	23
4 months after the accident	2
5 „ „	2
6 „ „ „ „	2
7 „ „	1
8 „ „ „	6
9 „ „ „ „	1
10 „ „ „	1
11 „ „ „ „	2
12 „	4
13 „ „	1
16 „ „ „ „	1
Returned to light work	3
10 months after the accident	1
15 „ „	1
16 „ „ „	1
Permanently unable to work	4
Retired on pension before the accident	2
Death	1
Total	33

Table 6 Complications in the treatment of 33 patients with multiple injuries

Complication	Number of cases
Fat embolism (7 before surgery)	8
Thromboembolic disease	2
Wound infection	5
Death (heart disease 80 years)	1
Pseudarthrosis	3
of distal femur	1
of tibia	1
of ulna	1

16 patients had a cerebral injury 18 a chest injury five an intra abdominal injury ten a pelvic *fracture four a fracture of the* sp ne one [illegible]

[illegible] ases within the first day (Table 2) At the same time

Table 7 Results of treatment of 33 patients with multiple injuries and operatively treated long-bone fractures

Result	Number of patients
Complete recovery with no disability	*12*
Recovery with slight disability	*14*
Recovery with severe disability	*6*
1 patient with paraplegia	
1 patient with hemiplegia	
1 patient with paralysis of brachial plexus	
1 patient with chronic alcoholism	
1 patient aged 68 years with severe limp	
1 patient aged 59 years with severe limp	
Death	*1*
Total	33

or at a separate operation additional procedures were indicated because of associated injuries (Table 3)

With primary operative treatment of long bone fractures of patients with multiple injuries it was possible to mobilize 30 patients out of 33 within three and a half months, and 29 were allowed to leave hospital within 4 months (Table 4) With the exception of the death of an 80 year old woman, no severe complications because of the treatment could be registered, and 22 patients returned to work within one year (Table 5) The fat embolism syndrome was not a contraindication for surgical intervention (Table 6) Twelve patients recovered completely, and 14 remained slightly disabled (Table 7) The results of these 33 operatively treated patients indicate the advantages of more active treatment of patients with multiple injuries and long bone fractures as opposed to the usual conservative treatment of to day

SKIN AND SOFT PART INJURIES IN 150 OPEN FRACTURES OF THE TIBIA

P A Tonnesen J Heerfordt & M Pers (Copenhagen Denmark)

The records of 150 consecutive open fractures of the shaft of the tibia treated at Dept M, Bispebjerg Hospital Copenhagen Denmark between 1958 and 1970 were reviewed in order to examine the relationship between the severity of the trauma, the method of treatment the number and type of complications and the time for recovery

140 cases were rated as high energy trauma according to the definition of Bauer et al., being roughly equivalent to grade 2 and 3 according to the soft part injury grading from 1 to 3 of Matter and Olerud 65 per cent of the cases were treated with plaster-casts alone or in combination with skeletal traction 35 per cent had conventional, non-compression plate osteosynthesis done Intramedullary nailing compression plates and osteotaxis were not employed in this series Decompressive incisions and split skin grafting were used fairly extensively In spite of this a

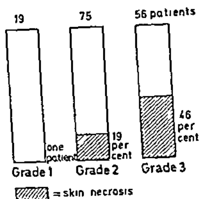


Figure 1

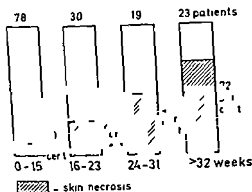


Figure 2

rather considerable incidence of skin necrosis occurred increasing with the severity of trauma (Figure 1)

The even more striking correlation between skin necrosis and delayed union is demonstrated in Figure 2

Well aware that no patent solution exists for the problems posed by open tibial fractures caused by high energy trauma we conclude that neither internal fixation nor plaster cast treatment seem to be ideal It is suggested that immobilization is instead accomplished by transfixation by the Hoffmann method and primary closure by a sufficiently critical and radical application of the principles of plastic surgery

FRACTURES OF THE SHAFT OF THE TIBIA TREATED WITH TRANSFIXATION

Erik Horlyck (Næstved, Denmark)

Thirty five patients with unstable fractures of the shaft of the tibia were treated with transfixation and plaster Steinman pins were drilled through the tibia transversely one or two on either side of the fracture Reduction was performed and a plaster cast applied from toes to groin The pins were kept in the plaster The patients were mobilized after one week when possible

Thirty two patients had comminuted fractures many with severe comminution and 24 had open fractures In 19 patients the fracture was situated in the distal part of the shaft sometimes including the metaphysis Secondary dislocation during transfixation was seen in four patients Transfixation was maintained for 2-3 months A shorter time of fixation resulted in a risk of secondary dislocation Loosening of the pins was seen in seven cases Suppuration from the pin holes occurred in four in all cases it was short lasting Immobilization in plaster continued until fracture healing was achieved In 15 patients this was achieved in less than 4 months in six from 4 to 6 months and in 14 it took more than 6 months Pseudarthroses developed in four patients In three cases of pseudarthroses the transfixation could not be held responsible With a follow up study we found only 10 per cent had a slight restriction in the movement of the knee joint In the ankle joint flexion/extension was restricted more than 10° in 25 per cent and inversion/eversion restricted more than one third in 10 per cent

FRACTURES OF THE TIBIA—A COMPARISON BETWEEN CONSERVATIVE TREATMENT PLATE OSTEOSYNTHESIS AND OSTEOTAXIS AD MODUM HOFFMANN

V Damholt & D Zdravkovic (Odense Denmark)

A series of 524 fractures of the tibia was reviewed. Sixty five per cent were traffic accidents Forty five per cent of the fractures were open Special attention was paid to skin infection ostitis pseudoarthrosis and amputation correlated to primary skin injury level of the fracture and degree of displacement Primary skin injury and displacement were found to be most important for the prognosis Pseudoarthrosis was most frequent in the proximal part of the tibia

The conservatively treated fractures had the shortest time of healing and the smallest number of complications Osteotaxis ad modum Hoffmann showed a lower frequency of ostitis and pseudoarthrosis compared with plate osteosynthesis.

510 fractures were healed nine cases still have support and four were amputated at the time of review

TREATMENT OF LEG FRACTURES

Gunnar Aas Aune (Trondheim Norway)

A 10 year survey of 2717 diaphyseal fractures in 1969 at this hospital showed a restrictive attitude to operative treatment of leg fractures in particular the open ones The frequency of pseudoarthrosis in 1103 leg fractures was 3 3 per cent

During the period 1970-72 a more enthusiastic attitude to surgery was attained and in the present survey a comparison of treatment and results of leg fractures

among adults during the years 1970 and 1973 has been carried out It appears that in both years 55 leg fractures were treated, the number of open fractures in 1970 and 73 being 12 and 8 respectively

In the groups treated conservatively the rate of complications was two out of seven and four out of 34 for open and closed fractures respectively whereas in the operatively treated groups the figures were two out of 13 and 19 out of 55

It is concluded, that open fractures should preferably be treated by operative methods, whereas closed fractures should have a more conservative treatment

SEGMENTAL TIBIAL SHAFT FRACTURES

O Langård & O Bø (Oslo Norway)

This report concerns a total of 54 cases with double fractures of the tibia treated during the period 1968–1972

Sixty eight per cent of the cases were pedestrians hit by a car Fifty two per cent were open fractures

Operative treatment predominated osteosynthesis was performed in 33 cases whereas 21 were treated conservatively Plate osteosynthesis was accomplished in 15 cases seven had intramedullary nailing and two were treated by Hoffmann s external fixation device Only one patient sustained a severe complication i e deep wound infection and osteomyelitis however even this infection was transient

All fractures healed except those in two patients who died within three months, these deaths however were without any causal relationship to the osteosynthesis

One patient had a traumatic vascular lesion concomitant with the fracture and his leg was amputated three days after the injury Another patient had his leg amputated one year after his accident this also because of injury to the vessels and nerves None of these amputations could be ascribed to the osteosynthesis

It is concluded from the present series that segmental i e double tibial shaft fractures do not entail more complications nor exhibit a slower rate of union than simple tibial shaft fractures if the treatment is individualized and also if due consideration is given to the soft tissue injury

TIBIA FRACTURES—EFFECT OF FRACTURE TYPE ON HEALING TIME AND NON UNION FREQUENCY

Valdemar Surin Goran Warkhede & Krister Sundholm (Borås Sweden)

The material is an analysis of 337 tibial diaphyseal fractures in patients over 15 years of age In analysing the sex distribution of the fracture patients a very high over representation of the male sex was appearent especially in patients with transverse dislocated fractures (ratio 6 1) This does not correlate with the sex ratio for traffic accidents (2 1) from the general Swedish statistics. One explanation may be the different mechanical behaviour of female tibial bone

The authors investigated by statistical methods the healing time for different fracture groups The most protracted healing time was in the transverse dislocated fracture group By investigating factors influencing the healing course, chronic suppuration was found to have the most deleterious effect. An open wound had a significant effect on fracture healing time only in transverse dislocated fractures

and only in wounds of grade 3 magnitude Factors of no significance were age sex and associated trauma Operation proved of no significant effect except on the 95 per cent values for both transverse and oblique fractures which were significantly lengthened

In statistically evaluating factors influencing development of non union the following were evident Factors without significance were age of patients and comminution of the fracture site Factors enhancing the risk for non union were operation especially osteosynthesis with Rush pins and cerclage and infection both recent and late Open wounds had a significant effect only when of grade 3 magnitude and continuous traction only in cases with more than 3 weeks duration

OSTEOMYELITIS AFTER OPERATIVE FRACTURE TREATMENT

Rolf Hagen (Bærum Norway)

During the years 1967 1972 a total of 50 patients with a history of 51 fractures were treated at Martina Hansens Hospital for osteomyelitis after osteosynthesis

The lower extremities were fractured in 88 2 per cent of the cases mainly tibia and femur and 56 9 per cent of the material were closed injuries The fractures mostly caused by traffic accidents and falls were immobilized by plates in 22 and intramedullary nails or pins in 21 patients

On admission staphylococci aurei were cultured in 41 cases (80 4 per cent) 70 per cent of them were penicillin resistant but in 32 out of 41 cases the organisms were highly lincosin sensitive and only three patients with four osteomyelitic lesions presented lincosin resistance

The treatment consisted chiefly of sequestrectomies and saucerizations supported by 3 12 months duration of lincosin treatment In 24 operations a closed irrigation suction technique was used perfusing the wound with lincosin solution It was found that intramedullary rods with rigid fixation should be left in place until the fracture is clinically solid

At follow up the results were recorded according to definite criteria and judged as good in 76 per cent fair 4 per cent and poor 20 per cent

The results are encouraging but the amputation rate was 14 per cent continuously emphasizing the therapeutic challenge posed by this type of osteomyelitis A certain reservation is probably reasonable in the use of osteosynthesis with plates in the case of comminuted tibial fractures with considerable damage to soft tissues

FINAL RESULTS OF OPERATIVELY VERSUS NON OPERATIVELY TREATED FRACTURES OF THE TIBIA

Erkki O Karaharju Jorma Nieminen & Antti Alho (Helsinki Finland)

A series of 160 fractures in 155 patients treated at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki is reported Eighty patients were treated operatively using an intramedullary nail in 33 an AO plate in 29 and screws in 18 cases The non operative group of 80 patients was selected so that there were no marked differences in wound complication fracture comminution localisation pattern or instability between the groups Two early and five late infections occurred in the non operative group In the operative group 23/80 patients developed an infection 6 33 operated on using an intra

medullary nail 11/28 using an AO plate and 6/18 using screws In the final evaluation an average of 3 years after trauma, the following findings were recorded using Edwards (1975) criteria pain working capacity, limp knee ankle and foot movement swelling amputation osteomyelitis and non union If any of these criteria was classified as poor (or fair) the final result was given correspondingly The result was classified as good in 39/80 fair in 27/80 and poor in 14/80 cases in the non-operative group and 40/80, 25/80 and 15/80 cases in the operative group The main delayed complaint was a loss of ankle or foot movement which was observed in 19 patients in both groups Leg swelling was observed in 13/80 patients in the non-operative and 16/80 in the operative group and it was recorded as the main complaint in 6/80 and 8/80 cases respectively Persistence drainage was found in 2/80 in the non operative and 4/80 in the operative group Fracture comminution had a statistically significant effect on foot and ankle movement

THE SOCIAL PROGNOSIS AFTER LEG AMPUTATION

Sv Rosendahl & M Møller Hansen (Copenhagen Denmark)

During the period 1970–71 eighty five patients had lower limb amputations at Kommunehospitalet in Copenhagen 9th Dept All the survivors 34 patients were followed up for two years after the operation particularly to illustrate the social prognosis

The mean age of all the patients was 72 6 years and 45 per cent died within the first year All the patients were amputated because of senile arteriosclerosis except for 11 cases of diabetic gangrene

No patient had a below knee amputation Fifty five patients were amputated through the knee primary healing was attained in 21 cases and 24 underwent secondary above knee amputation A total of 54 above knee amputations resulted in primary healing in 33 cases

The follow up series consists of 22 men and 12 women Eighteen patients lived at home sixteen patients in institutions Thirty amputees were fitted with prostheses but only 18 used their prosthesis Fifteen patients were able to walk well inside and outside and to care for themselves without help An analysis of the wheelchair patients and those who used their prosthesis showed no difference in age and level of amputation but 12 men and only three women were able to walk well

Unsuccessful fitting and bilateral amputation were essential causes of failures in prosthesis walking

Fifty per cent of the amputees in the whole material were not fitted with a prosthesis because of severe cardio vascular and pulmonary disease in half of the cases and debility and bilateral amputations in the rest of the cases Only one among 12 bilateral amputees was able to walk well

LEG AMPUTATIONS IN A DANISH COUNTY 1961 71 WITH A FOLLOW UP STUDY

Sten Christensen Aalborg, Denmark)

In the period 1961 71 the County of Aalborg had 240 000–260 000 citizens and 372 extremities on 321 patients were amputated (14 9 per 100 000)

The indications for 326 amputations were vascular diseases of these 101 were

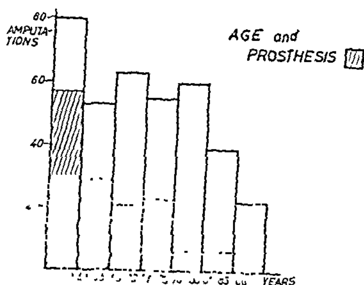


Figure 1

combined with diabetes and 14 had previously undergone a vascular-operation Twenty-nine were amputated after trauma

The duration of the symptoms varied from weeks to years, on average 29 5 weeks for arteriosclerotics and 23 2 weeks for diabetics

Most of the amputations were above the knee 268 against 102 amputations below the knee and 2 at the knee

The occurrence of complications for arteriosclerotics and diabetics were equal in frequency (approx 25) but above knee amputations were safer with 19 per cent sustaining complications against 42 per cent with below knee amputation Twelve of the below-knee amputations were later amputated above the knee

Diabetics could more frequently be amputated below the knee, and diabetics were operated on an average of 3 years younger

Table 1

DIAGNOSIS and LEVEL

	below knee	re-amp	above knee	
ARTERIOSCL	33	8	142	175
DIABETES	56	3	95	151
TRAUMATIC	11		18	29
TUMOR	2		7	9
OTHER	2	1	6	8
	104		268	372

ARTERIOSCL	19% → 14%	BELOW KNEE
DIABETES	37% → 35%	— " — — " —

The postop[illegible] per cent after 3 months 31 per cent of the [illegible] 1 year arterioscler[illegible] in both group[illegible] below

Out of the 372 amputated 73 died postoperatively [illegible] knee and 119 above knee prostheses) Of these at least four below knee and 23 above knee prostheses were not in use

The average time from amputation to ambulation was 18 weeks

195 of the 299 survivors were discharged to their homes

3 13 years after amputation 62 out of 321 patients are alive 24 are at work, nine work at home 55 are in their homes

50 out of 62 have light to medium phantom pains three have severe pains

PATIENTS OF TO DAY WITH LEG PROSTHESES—A SIX YEAR SERIES

Bjorn M Persson Tage Plym & Beth Brunk (Lund Sweden)

During the last decade lower limb amputation was carried out below the knee more often than above as was the case earlier Success depends on better general care and better surgical care To see what influenced this better regimen had had on the patients all amputees possessing a prosthesis were compared to the patients amputated during the same period with special attention to the functional difference between below and above knee fittings

Material and Method

During 1966–1971 207 patients were amputated in Lund 83 per cent being ischemics Meanwhile the workshop delivered temporary prostheses to 94 and permanent prostheses to 365 amputees With 73 dead 10 not traceable and 127 from other hospital regions 165 were contacted and 146 came for reexamination by a physiotherapist in 1973 Evaluation was made of gait stump condition including range of movement and strength of both limbs type and condition of prosthesis ADL status and general condition of the patient in total 80 data for each case all analyzed in a computer

Results

Only 18 no longer used the device 16 because of their general condition In the group walking only 50 per cent were ischemics reflecting the death rate in this group compared to the trauma group in this group 55 per cent were BK, whereas in the ischemic group 64 per cent were BK Age distribution in BK and AK was almost the same allowing statistical comparisons Evident decrease in ROM was found in 15 per cent in AK and 5 per cent in BK patients but was not statistically correlated to the functional parameters Loss of muscular strength was also found to be of little importance but was common in the quadriceps of BK amputees with thigh corset devices Stump abrasions and inequality of leg length in standing were found in 40 per cent both in BK and AK but gait abnormalities differed significant[illegible] lateral bending and abduction was normal in all but the PTB users Freedom from gait supports good walking distances unassisted ADL and donning and doffing were significantly better in the BK than in the AK especially in the ages above 64 Most patients were unaware of defects found and an active check up pro

gram is indicated as with automobiles Special attention is necessary with the early preliminary fittings since many geriatrics never survive to reach the fully trained stage with a normal permanent prosthesis

THE USE OF A PROSTHESIS IN LOWER LEG AMPUTEE PATIENTS

Poul Ramsing & Soren Pilgaard (Arhus Denmark)

During the period 1965 1969 a total of 254 patients with lower leg amputations were treated with a prosthesis at the Orthopaedic Hospital Arhus The average age for the 88 females is 62 7 years and for the 166 males 53 8 years Of the patients, 58 per cent died after an average of 3 3 years Of those still alive (28 females and 78 males) it was found an average of nearly 7 years after the prosthetic supply that 78 per cent of the patients were able to use the prosthesis every day and all day

Nine out of 16 patients alive treated with bilateral prostheses could only use the prostheses for a few hours daily or had given up prosthesis use. Six of these were supplied with bilateral femur prostheses

AMPUTATIONS IN 1970 IN FINLAND

K Solonen C C Lindqvist (Helsinki Finland)

Data about major extremity amputations i e loss of at least four fingers or five toes were collected from all hospitals in the country In 1970 78 amputations on the upper extremity and 800 on the lower were carried out In that year the population was about 4 700 000 and the rate of these major amputations was estimated at two per mille In the group of upper extremity amputees 13 per cent of the cases were female and 87 per cent male Their median age was 41 2 years and the amputations were overwhelmingly due to industrial accidents In the group of lower extremity amputees correspondingly two fifths were female and three fifths male and the median age was as high as 68 8 years Vascular diseases dominated as a cause of amputation There were only 10 per cent which were accident cases and nearly every second one of these had sustained a cold injury of the feet

HEMIPELVECTOMIA

Frank Ole Petersen (Copenhagen Denmark)

During the period 1952 1974 a total of 50 patients with malignant tumours were treated with a hemipelvectomy operation The 5 year survival rate was 26 per cent

Thirty four patients were supplied with a prosthesis of the Canadian type About 66 per cent became daily wearers of artificial limbs Eighteen patients returned to work and three to homemaking Further details will be published in this periodical

DANISH AMPUTATION REGISTER D A R NATIONWIDE RECORDING OF AMPUTEES AND PROSTHESES

Bent E Ebskov (Copenhagen Denmark)

The D A R records present and future amputees in Denmark to obtain statistics on the amputee population for analysis of etiological factors operative detail

incidence and type of complications and reamputation, per- and postoperative death duration of hospitalization, mobility on discharge and social information The D.A.R. records the prostheses delivered, to generate statistics on the number and type and to analyze technical aspects relative to the prostheses Later the register may yield trend analyses for estimation of future needs of personnel facilities and economy

The structure of the register permits the selection of groups of amputees for in depth analysis by clinical and social examination

Since mid 1973 659 medical reports on amputations were received from 55 departments 338 prosthetists reports have been received since the end of 1973 The national coverage for both categories is stipulated at two thirds of the total

The first 500 medical reports have been analyzed and the results described

HIGH OR LOW PLASTER FOR FRACTURED SCAPHOID

Antti Alho & Uolevi Kankaanpää (Helsinki Finland)

During 1970-71 one hundred consecutive patients with a fractured carpal scaphoid were treated at the Department of Orthopaedics and Traumatology Helsinki University Central Hospital At random 53 fractures were immobilized with the customary plaster from the interphalangeal joint of the thumb to below the elbow In forty seven patients an above elbow plaster of Verdan was used for 6 weeks (*Surg Clin N Amer* (1968) 48 1083) When necessary the immobilization was continued using a below elbow plaster No differences in the type or localization of the fracture occurred between the groups The plaster was removed at 2 week intervals to check the consolidation by x ray and palpation In eight cases consolidation was not achieved in 3 months and an AO screw fixation was performed followed by a plaster slab for 2 to 6 weeks when required All fractures united Excluding these eight patients, the immobilization time was 48 1 ± 2 7 days (mean ± S.E.) in the low plaster group and 49 1 ± 3.8 days in the high plaster group In conclusion a below elbow plaster gives an adequate immobilization for fracture of the scaphoid an osteosynthesis is warranted if bony union is not achieved in 3 months

THE EFFECT OF ARDUOUS INDUSTRIAL WORK ON THE SHOULDER JOINT

Peter Herberts Roland Kadefors & Ingemar Petersén (Goteborg Sweden)

Using an electromyographic method clinical examination and soft tissue radiography the effect of heavy industrial work was evaluated using welders at a ship yard in Goteborg Unexperienced experienced and old welders were studied during standardized tasks Thirty welders were included in the electromyographical study and ten old welders were also examined clinically and roentgenologically

It was found that spectral variations of EMG indicative of localized muscle fatigue were present in welders in over head production work The effect was present and significant in the supraspinatus muscle and the trapezius muscle and for unexperienced welders also in the deltoid muscle This is illustrated in Figures 1 and 2 The old welders with chronic shoulder pains had a normal range of movement but significantly reduced gross power with respect to flexion, abduction and

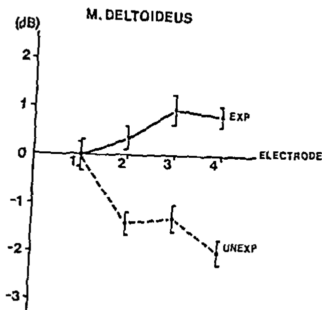


Figure 1 Spectral changes within a high frequency component (500 Hz) in Emg during welding, indicating muscle fatigue Note the difference between experienced and unexperienced welders Over-head welding

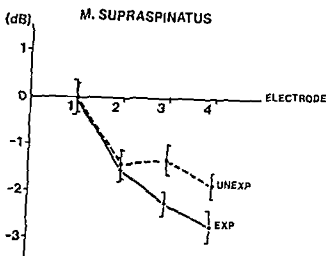


Figure 2 Spectral changes indicating muscle fatigue for both experienced and unexperienced welders with respect to the supraspinatus muscle

rotation The roentgenological study showed an inflammatory reaction in the soft tissue lateral to the rotator cuff of the shoulder joint Our results indicate that over head welding will constantly fatigue especially the supraspinatus muscle and after many years a chronic peritendinitis of this tendon develops This is probably the reason for the very common shoulder pain syndrome affecting old welders The knowledge obtained may lead to demands for change in the production lay out or in the planning of the individual work situation

FEMORAL NERVE COMPRESSION SYNDROME WITH PARESIS OF THE QUADRICEPS MUSCLE CAUSED BY RADIOTHERAPY OF MALIGNANT TUMOURS

A Report of Three Cases

L E Laurent (Helsinki, Finland)

Tissue lesion due to radiotherapy, which causes compression of the femoral nerve and paresis of the quadriceps muscle, is obviously rare because no reports have been found of this complication in literature on the subject After treatment of cancer of the breast by radiation, similar symptoms in the upper limbs, of compression syndrome of the brachial plexus, have been reported (Westling et al 1968, 1972 Mumenthaler 1964, Stoll & Andrews 1966, Notter et al. 1970)

Three patients with compression syndrome of the femoral nerve were treated at the Orthopaedic Hospital of the Invalid Foundation, Helsinki

One patient had cancer of the uterus, one cancer of the right ovary, and the third patient a malign melanoma of the skin with later a metastasis in the right inguinal region

The radiation treatment caused compression on the femoral nerve by X ray damaged tissue The first symptom of nerve compression was a pain which radiated in the front of the thigh and also in the medial part of the upper leg The pain appeared 12 to 16 months after radiation therapy and was irregular, usually being worst during rest Several months after the pain had begun a decrease in the power of the quadriceps muscle occurred and two of the patients had difficulty in walking. EMG investigations showed typical signs of a peripheral lesion of the femoral nerve.

In the first case a decompression of the femoral nerve was performed and it was seen to be compressed by scar tissue Pain greatly decreased after the operation but paresis of the quadriceps muscle remained unchanged

In the second case in which the compression was apparently slight, the pain disappeared after two months treatment with cortisone and oxiphenbutazone The paresis of the quadriceps muscle had almost disappeared six months later

In the third case a very severe pain disappeared after indural phenolglycerin injection The palsy of the quadriceps muscle here seems to be permanent and deliberation of the femoral nerve gave hardly any further improvement

A change in the techniques of radiation therapy is obviously needed With radiation doses which are successful in treatment, the risk of such complications probably cannot be entirely eliminated (Westling et al)

LATE RESULTS OF LAMINECTOMY IN THE TREATMENT OF LUMBAR SPONDYLOLISTHESIS

A Osterman L E Laurent & S Lindholm (Helsinki, Finland)

In the Orthopaedic Hospital of the Invalid Foundation a total of 130 laminectomies were performed between 1953–71 Of these 50 patients with a follow up of 5 years or more were re examined. The follow up time was 12 years on average Thirty nine patients were men, 36 women Four patients were under 20 years of age 53 (71 per cent) belonged to the age group 40–59 Most patients had chronic low back or radiating pain, about one third had some neurological findings Two

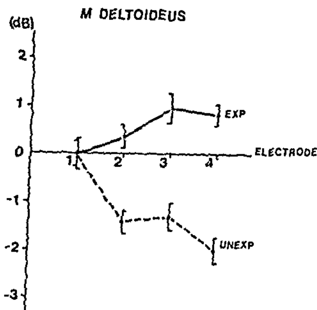


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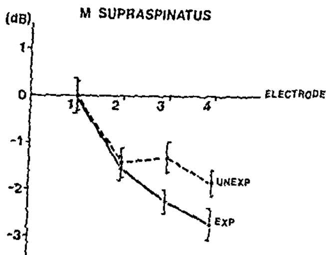


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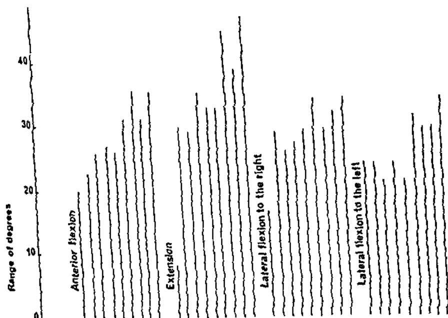


Figure 1 A bar chart showing the change of mobility of the spine during treatment in one patient with left sided sciatica Each bar indicates one clinical check up

With advancing years the range of motility will decrease and the pattern of spinal movements is found to become so to speak, more narrow

In a status of motility the restrictions of range will be marked out and in particular they are conspicuous in asymmetric motility of the lateral flexion and the torsion

In this material of 63 patients with chronic low back pain the lumbago sciatica syndromes account for 90 per cent Except for three patients measurable restriction in one or more directions was noticed

The patients were given a uniform conservative treatment An immobilising plaster of Paris corset followed by active physical training of the spine muscles

It can be demonstrated that the pattern of motility in a typical low back pain patient changes as the cure proceeds The various movements are generally increased

The material was by clinical judgement divided into three clearly defined groups A consisting of 35 patients with a good improvement B) 15 with some improvement and C) 9 with no noticeable improvement

Group A had the greatest increase of motility in particular in the lumbar spine, followed by group B whereas group C developed a further rigidity of the spine during treatment

The examination shows that frequently spinal rigidity accompanies low back pain syndromes When the condition improves motility increases This indicates the good effect of the therapy used

Table 1. Late results of laminectomy in different age groups

Age	Excellent	Good	Fair	Poor	Total
< 20	1	1	2	–	4
20–29	2	4	–	–	6
30–39	–	5	3	3	11
40–49	–	12	9	10	31
50–59	1	7	8	6	22
60–	–	1	–	–	1
Total	4	30	22	19	75

of the adolescents had progressive neurological findings and a total olisthesis Lumbar disc herniation was found in nine patients

The late results of surgery are presented in Table 1 The result was classified as excellent if the patient was symptomless, good if there was slight pain on exercising, fair if the patient felt better after surgery but had some symptoms, and poor if no relief of symptoms was achieved or further operative treatment was necessary.

Twenty-five per cent of the patients had a progression of slipping of 3 mm or more Two of these patients were adolescents The progression of slipping had no effect on the subjective symptoms and seemed to depend on the stability of the underlying disc Very often the symptoms seemed to be due to the degenerative changes in the lumbar spine Neurological findings remained unchanged and local tenderness in the operated area was a constant phenomenon In general the results were better if the patients had moved to lighter work or retired after or shortly before operation

The operation seems to be best suited to elderly patients with chronic low back or radiating pain, it is contraindicated in children and adolescents because of the risk of further slipping except in cases with a total olisthesis and posterior compression of the cauda by the lamina

SPINAL RIGIDITY IN RELATION TO LOW BACK PAIN

Kåre Haug (Gjøvik Norway)

Stiffness of the back is best charted by measuring the motility of the thoraco-lumbar spine in relation to the pelvis and the median plane of the body The range of motility is read off in degrees except for the lumbar spine where it is read off in millimetres of deviation

The base line for flexion extension movement is located in the dorsal plane of the sacrum, for lateral flexion it is in the median plane and for torsion it is situated in a frontal plane

The writer of this paper has constructed spondylometres with a wide scale to obtain an exact reading For lumbar lateral flexion in particular the deviations of a point 10 cm rostral to the lumbo-sacral junction are noticed

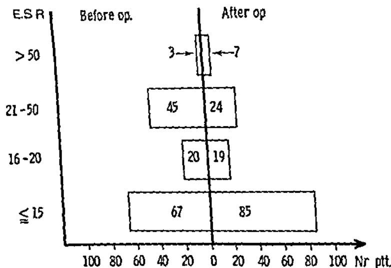


Figure 1

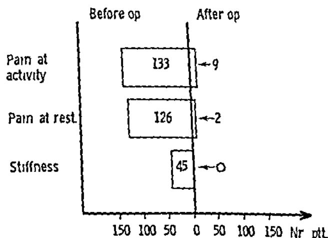


Figure 2

only in three cases after operation One patient was anticoagulated before and 22 after the operation One patient died of a pulmonary embolus (½ per cent)

The results of the 170 operations as regards complications are compared with a follow up from April 73 of the 123 hips operated on in the old operating room (average follow up time 25 months)

Wound secretion (3 per cent) and subcutaneous infection showed no change in the two materials Secondary infection with positive culture after 3 months fell

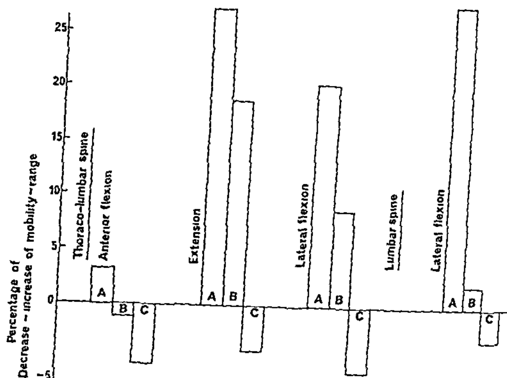


Figure 2 Mobility of the spine related to conservative treatment Three categori of improvement A) good B) some and C) no

A merely mechanical obstacle as a prime cause of the stiffness in some case cannot be excluded

Therefore a conspicuously diminished lumbar lateral flexion especially i asymmetric, may indicate disc protrusion with root affection

170 HIPS OPERATED *AD MODUM* CHARNLEY IN A CLEAN AIR OPERATING ROOM

S Pilgaard (Arhus Denmark)

In 1969 Professor Thomasen took up the total hip replacement *ad modum* Charnley at the OHA The first 123 hip operations were carried out in an old operating room Since October 1971 the Weber type of sterile enclosure has been used The principle of the Weber sterile enclosure is described

From October 1971 to June 1974 365 hip replacements have been performed in the sterile enclosure. 170 of these operations have been followed up (1st October 71–31st December '73 average follow up time 17 months) 170 hips in 135 patients (57 men 35 bilateral)

The 170 hips are homogeneous in the following respects operated on by the same surgeon, using exactly the same technique all having been pre operatively vaccinated with staphylococci vaccine No antibiotics were given before operation,